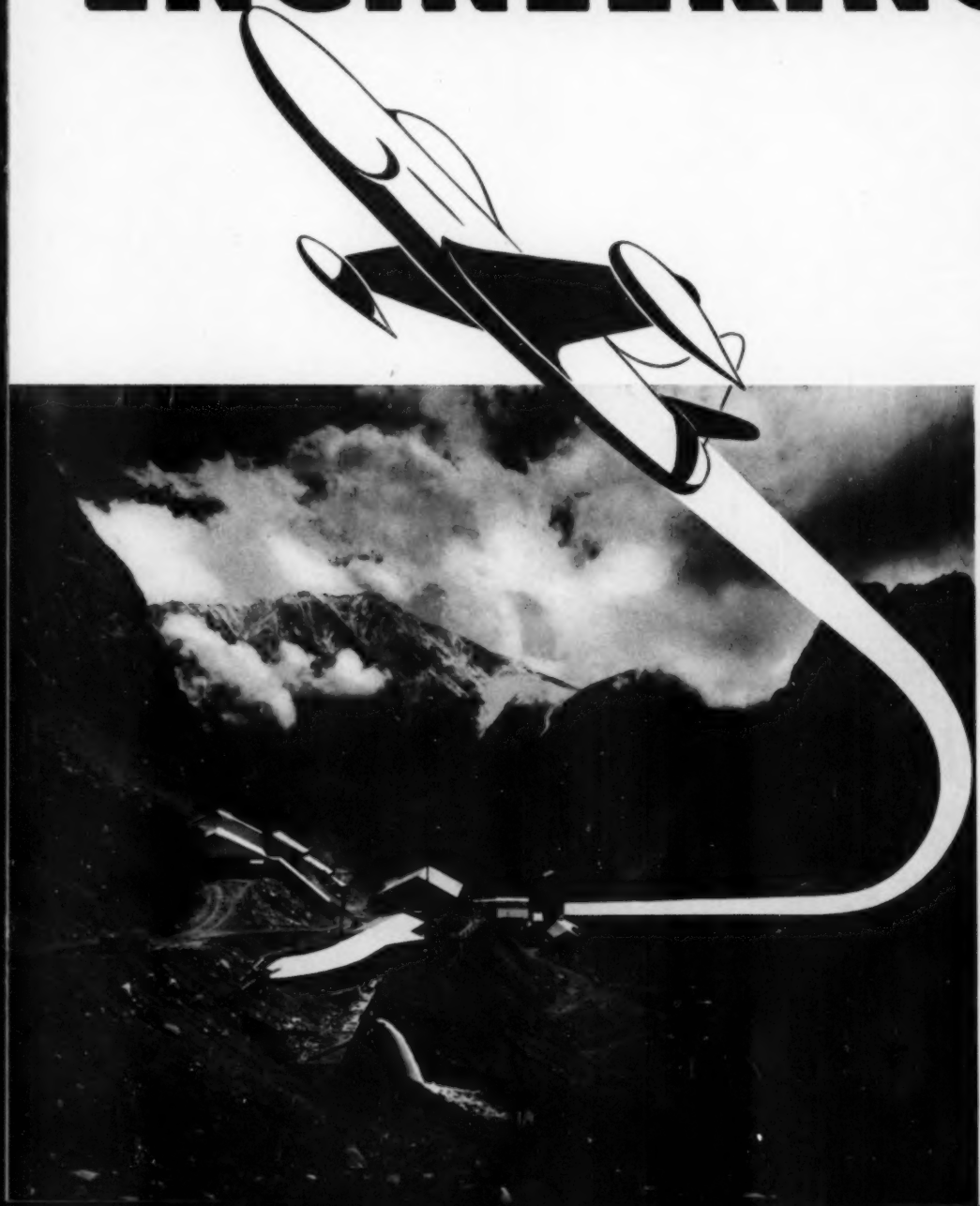
MINING ENGINEERING

OCTOBER 1951



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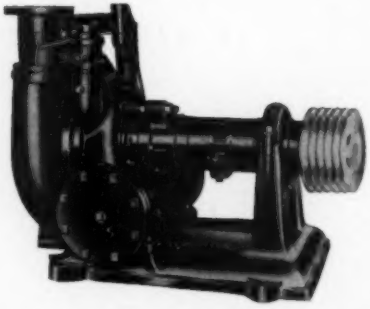

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MINING ENGINEERING

Incorporating Mining and Metallurgy, Mining Technology and Coal Technology

VOL. 3 NO. 10 OCTOBER, 1951

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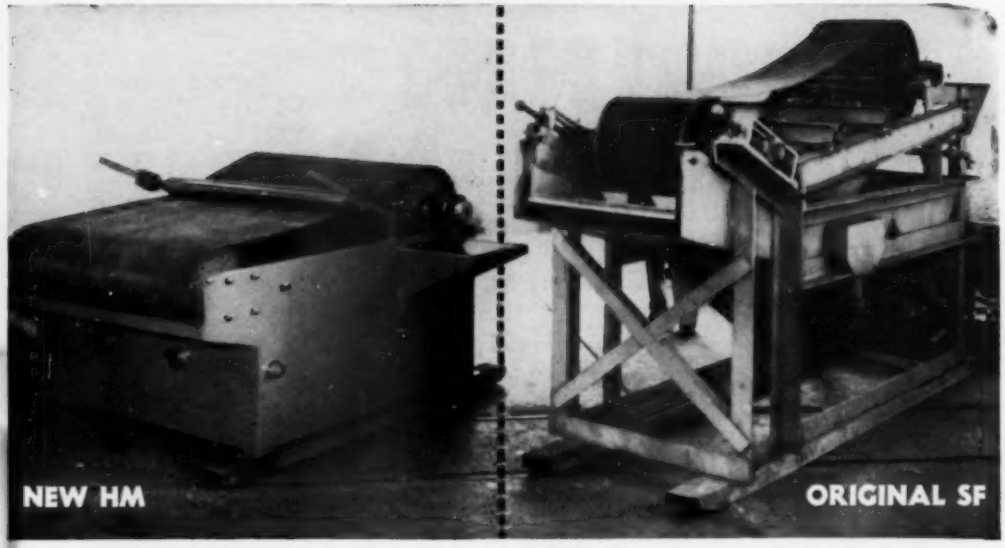
COVER: Symbolizing the flow of tungsten from high in the Sierras to the jet air craft of the Armed Forces. The Pine Creek mine (shown on cover) of U. S. Vanadium Co. near Bishop, Calif., is the largest United States producer of tungsten which is vital to American industry for use in light filaments, cutting tools, and refractory alloys.



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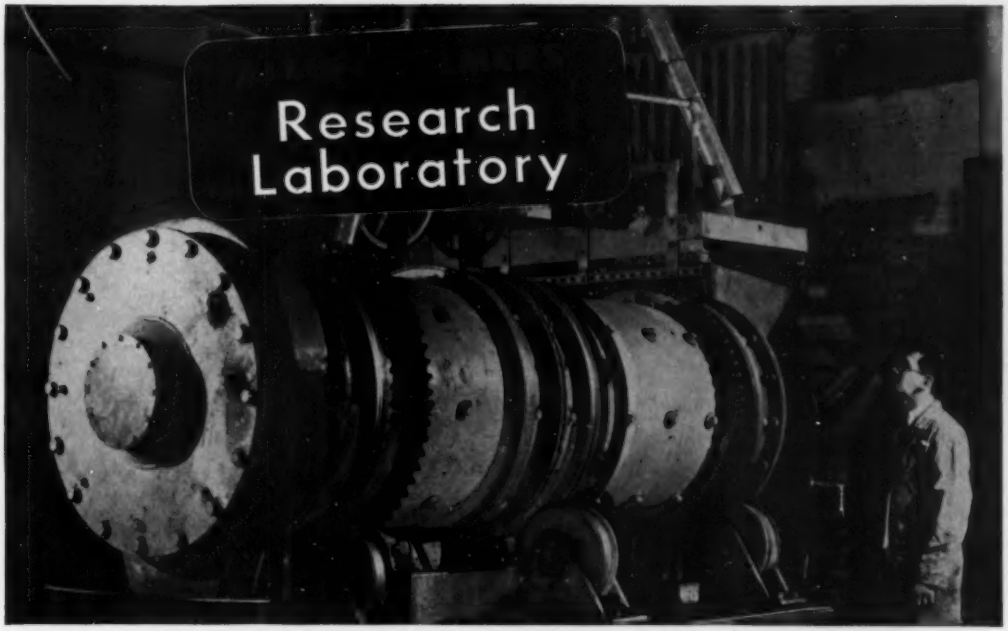

How Lab Tests Reduced Initial Plant Cost

A MINING COMPANY wanted to find a low cost method of crushing and dry grinding lead slag to a carefully controlled product of 98% passing 10 mesh. A method had been worked out previously which would meet these size specifications but which required a considerable amount of costly auxiliary equipment. The customer hoped that a simpler method might be found.

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Letters to The Editor

(The following is a comment on "Research in Coal Geology," by Gilbert H. Cady, which appeared in Mining Engineering, Feb. 1950, p. 275.)

WE have read Mr. Cady's article with real interest. . . . The need for more research in the field of coal "geochemistry" has . . . been fairly widely recognized for a number of years, and it is certain that coal will not be used to the best advantage until we have learned to rely on more fundamental testing methods than proximate and ultimate analysis. . . .

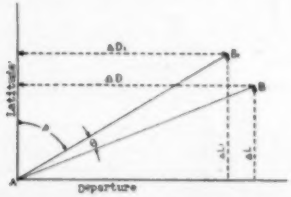
Our own work has forced us to the conclusion that the behavior of coals is determined more by their physical than their chemical constitution, and hence paramount importance attaches to what, by Mr. Cady's nomenclature, would be termed coal "geophysics." By this we do not mean the type of microscopic study foreshadowed in the article, but a detailed examination of the ultrafine—or colloidal—structure of coal. Experimental methods . . . have to a large extent been developed and adapted . . . but the field has not, in general, received the attention it so obviously merits. . . .

. . . Coal research has in the past been too parochially-minded. Virtually every industrialized country has undertaken comprehensive coal surveys . . . but the watch word . . . has been isolation at all costs. Part of the cost has been a multiplicity of standards (ASTM, BS, French, German, Russian, etc.) . . . and mutually exclusive classification systems. All these, be it noted, were based on a study of a comparatively narrow range of coals of similar type (i.e. northern hemisphere carboniferous coals laid down under tectonically similar conditions.) . . . We have been studying a wide range of Commonwealth coals, mostly from the southern hemisphere, and were immediately forced to scrap virtually every correlation and classification at present in vogue. To some extent it has been possible to replace these by more generalized (if less precise) relationships. . . . Work could no doubt be speeded up . . . by closer international cooperation, at any rate among coal research workers in countries where mental blinkers are not a prerequisite for physical survival.

N. BERKOWITZ and H. G. SCHEIN
LONDON, ENGLAND

Commenting on J. Paul Trueblood's article on "Computing Survey Notes with Traverse Tables" in MINING ENGINEERING, *July 1951, p. 583, is the following letter from overseas:*

MR. Trueblood could with advantage have enlarged upon the method he employs for interpolation when the bearings of the traverse lines have been determined to the nearest second. The method of interpolation generally employed by British mine surveyors may be of interest to some of your readers.



In the above figure AB is a traverse line of length L and quadrant bearing $(\rho+\theta)$ where ρ is the value of the degrees and minutes and θ the seconds of the angle (i.e. in a quadrant bearing N49° 55′ 38″ E, ρ = 49° 55′ and θ = 38″)

Suppose $AB_1 = AB = L$

Then from the figure

$$\Delta D_1 = L \sin \rho$$
$$\Delta L_1 = L \cos \rho$$

and

$$\Delta D = L \sin (\rho+\theta)$$
$$= L \sin \rho \cos \theta + L \cos \rho \sin \theta$$

Similarly

$$\Delta L = L (\cos \rho + \theta)$$
$$= L \cos \rho \cos \theta - L \sin \rho \sin \theta$$

Substituting ΔD_1 & ΔL_1 for L sin ρ & L cos ρ respectively, we get

$$\Delta D = \Delta D_1 \cos \theta + \Delta L_1 \sin \theta$$
$$\Delta L = \Delta L_1 \cos \theta - \Delta D_1 \sin \theta$$

Now since θ is small (it is never greater than 59″) these equations become

$$\Delta D = \Delta D_1 \cos \theta + \Delta L_1 \frac{\theta \text{ secs}}{206{,}265}$$

$$\Delta L = \Delta L_1 \cos \theta - \Delta D_1 \frac{\theta \text{ secs}}{206{,}265}$$

Consider the fractions $\frac{\theta \text{ secs}}{206{,}265}$ with values of θ equal to 10, 20, 30, 40 and 50 seconds

Value of θ in Seconds	Approximate Value of $\frac{\theta \text{ secs}}{206{,}265}$	Error in Adopting the Approximate Value
10	1/10,000 ÷2	1/659,000
20	1/10,000	1/329,500
30	1/1,000 ÷7	1/400,000
40	1/1,000 ÷5	1/164,230
50	1/1,000 ÷4	1/132,000

It can be shown that the maximum error incurred in computing the position of a point due to approximating the quadrant bearing to the nearest 10 sec is about 1/40,000 (Methods of calculating elementary surveys. H. G. Smith. Colliery Engineering, Lond. July, 1947. 217-20.) which in combination with the errors incurred by interpolation give rise to a maximum error which is negligible compared with those which are likely to be incurred in mine surveying practice.

The values of ΔL_1 and ΔD_1 are read directly from the tables as explained by Mr. Trueblood and the interpolation is as follows:

Suppose that AB = 681.56 ft and the Quadrant Bearing is N 48° 55′ 38″ E. Referring to the tables:

length.		Lat.		Dep.
680		446.17		512.55
1		0.66		0.75
0.56		0.37		0.42
681.56	ΔL_1 =	447.20	ΔD_1 =	513.72
$\Delta D_1/1{,}000 \div 5$	=	−0.10	$\Delta L_1/1{,}000 \div 5$ =	+ 0.09
		447.30		513.81

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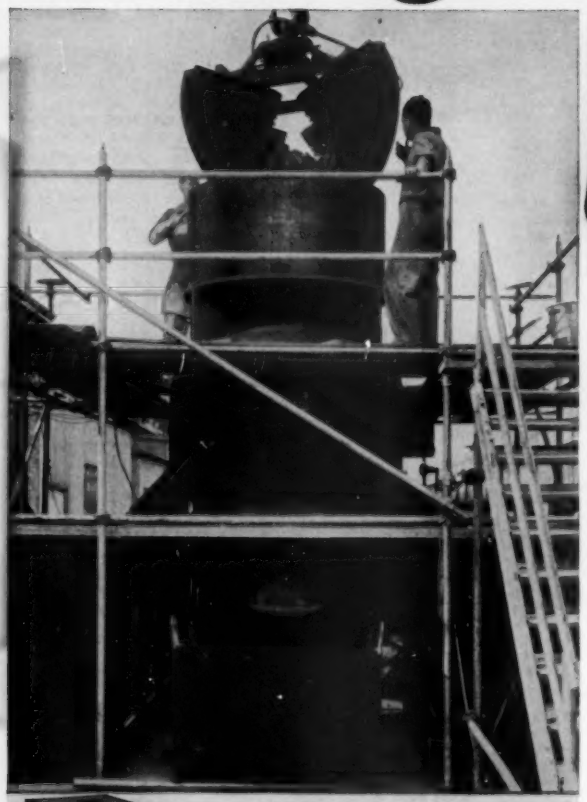

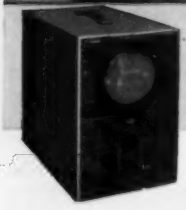

Oscillograph readings of strain on *Hydrocone* crusher were made at various points on the topshell spider, topshell, bottomshell and bottom plate. Test was made in A-C Processing Machinery laboratory by Allis-Chalmers engineers.

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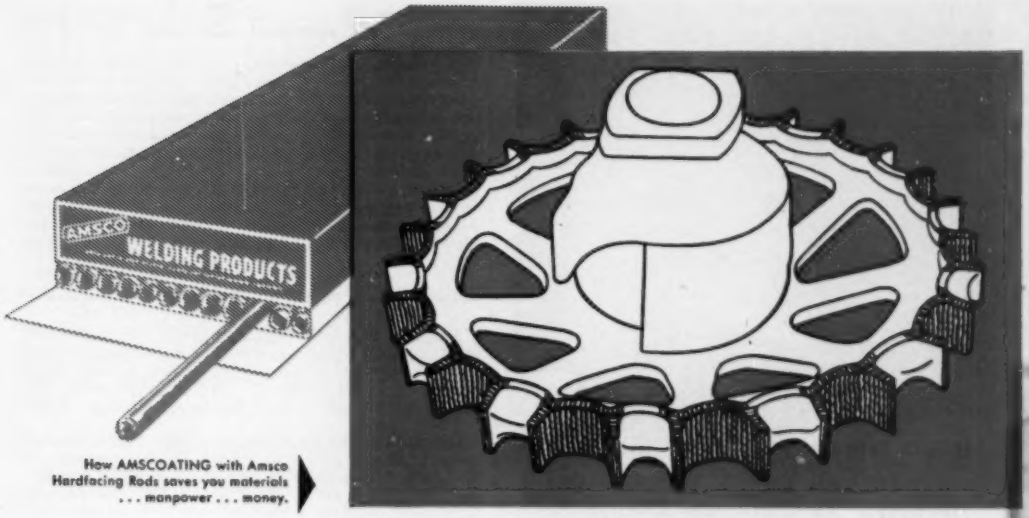

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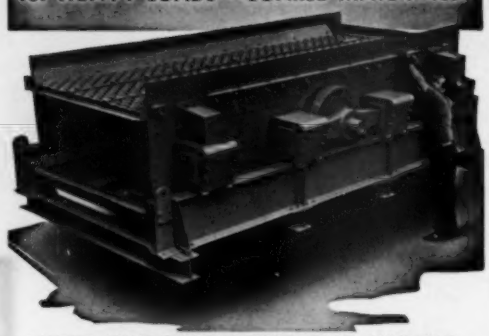

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Mining or Mechanical Engineer with coal production and preparation experience, to supervise installation, operation and maintenance of coal preparation plant. Salary, $12,000 a year. Duration, two years. Location, Turkey. Y5891.

Mine Shift Boss, single, with good working knowledge of Spanish. If a graduate mining engineer, extensive experience not required, otherwise, should have more underground experience. Mine is a gold-silver producer, with a milling capacity of 300 tons per day. Living conditions good. Salary, $3000-$3600 a year. Location, Central America. Y5888.

Mining Engineer capable of making base maps of various mine levels from various survey records. Should be able to draw primary coordinates and plot the coordinates of the various stations on the map. Following this, engineering work in connection with the construction work for expansion of mill. The work then could develop into underground surveying and possibly underground supervisory position as shift boss. Will consider recent graduate. Single status. Salary open. Location, South. Y5690.

Engineers. (a) Mine Master Mechanic and Chief Electrician with responsible experience in mechanized coal mining, to supervise installation and maintenance of underground mechanical and electrical equipment of large, highly mechanized potash operation. (b) Plant

Master Mechanic and Chief Electrician for same operation, to supervise machine shop and maintenance of mill and refinery mechanical and electrical surface equipment. Salary open. Location, Southwest. Y5664.

Engineers. (a) Superintendent for ore storage drying and grinding departments. Should have considerable operating experience in handling personnel and equipment of a large concentration mill, handling large amounts of ore, i.e., 5,000 tons/day. (b) Superintendent for an ammonia recovery plant, experienced in an oil refinery, by-product coke oven plant or large chemical plant involving distillation and/or similar processes. Salaries, $4800-$7200 a year. Location, Cuba. Y5602.

Fellowship—Mines and Metallurgy, B.S. or better, with knowledge of flotation processes, to investigate slime phenomena during flotation, particularly iron ore. Three year fellowship with opportunity to earn Ph.D. Salary, $1980 first year and increased to $2400 when selectee proves he has initiative; $175 a year extra also provided. Location, Minnesota. T8107.

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Mining Engineer, Superintendent, with fourteen years' experience in Alaska, western and southern states, conditioned by difficult operational, supply, construction, manpower, and geographical problems and locations. Any location acceptable where future is assured by proven results. M-642.

Graduate Mechanical Engineer, 31, married, 2 children. Seven years' responsible position in metal mines, shops, diesel plants, design and layout underground machinery in Bolivia. Prefer South America. Available October 1st. M-645.

Mining Engineer, 37, married; six years' experience U. S. mines including mine layout, plant design, surveying, mapping, underground; surface, land, topographic, triangulation. Experience shift boss and bonus incentive systems for production. Desires job in mining or civil engineering, preferably California or states adjoining. M-647-517-E-5-San Francisco.

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MINING ENGINEER, 37, experience operation, examination, U. S. and foreign. Available for interview at American Mining Congress meetings in Los Angeles, October 22-24.
Box H-18 MINING ENGINEERING

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WANTED— for field work, a graduate Civil or Mining Engineer with some experience in road building and construction. Age 30 to 40, good health, knowledge of Spanish essential. Location—Caribbean. Please write stating education, experience, references, etc. Box I-19. MINING ENGINEERING.

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Meet The Authors

SHIOU-CHAN SUN

Thomas P. Clendenin *(Metal Deposits in New Mexico, P. 861)* was born in Baton Rouge, La. and attended the City College of New York and Columbia University. He received his B.S. in 1916 and his E.M. in 1921. Besides holding membership in the AIME, he is a member of Geological Society of America, Society of Economic Geologists and American Assn. for the Advancement of Science. After receiving his engineering degree, he spent two years as an instructor in mineralogy at Columbia University. In 1923 he joined the Mexican Mining Dept. of the American Smelting & Refining Co. and has continued with them since that time. He has been chief geologist of this company since 1927 and his work in this position has taken him over a great deal of Mexico, partly in connection with the operations of the company and partly on the examination of new properties. Mr. Clendenin is particularly interested in problems of metalliferous deposits.

T. L. Kesler *(Occurrence and Exploration of Georgia's Kaolin Deposits, P. 879)* was born in Salisbury, N. C. and attended the University of North Carolina. He received his B.S. degree in Geology in 1929 and his M.S. in 1930. He has worked as assistant geologist for Shell Petroleum Corp. and also worked in the Central and Western states as soil conservation service engineer. He is at present time working for Thompson Weinman & Co. as geologist in charge of mineral exploration. Besides being a member of AIME, Mr. Kesler also holds membership in Geological Society of America, Society of Economic Geologists and Phi Sigma Kappa Fraternity. At present time he is Southeastern vice-chairman of Industrial Minerals Div. for 1951-52. Mineral exploration is Mr. Kesler's chief interest and photography is his favorite hobby.

W. A. Longacre *(The Hotchkiss Superdip as a Vertical Intensity Magnetometer, P. 891)* attended Michigan College of Mining & Technology and received his B.S. degree in 1929 and his M.S. degree in 1941. He is particularly interested in geophysical interpretation and instrumentation. He presented a paper before AIME in 1941 on "Depth Determination By Means of Earth Resistivity Measurements". Mr. Longacre has been employed by Mining & Milling Service Co. as consulting geophysicist and held a similar position with Consolidated Mining & Smelting Co. of Kimberley, B. C. Mr. Longacre is a member of Society of Engineering Geologists and American Society of Engineering Education. Golf and fishing are his favorite pastimes.

Orville R. Lyons *(Filter Cake Size-Consist and Moisture Relationships, P. 868)* has worked as a junior mining engineer for Philadelphia & Reading Coal & Iron Co. and was employed by Battelle Memorial Institute as research engineer in charge of coal preparation. He is now employed by Heyl & Patterson as coal preparation engineer. He was born in Staples, Minn. and attended the University of North Dakota and the University of Alabama receiving his B.S. and M.S. in engineering mining. An AIME member, Mr. Lyons presented a paper on "The Thermal Drying of Fine Coal". Mr. A. C. Richardson was co-author. His hobbies include sketching, woodworking, stamp collecting and his four children. Mr. Lyons is now residing in Pittsburgh.

Shiou-Chan Sun *(Destruction of Flotation Froth with Intense High Frequency Sound, P. 865)* attended Pei-Yang University in Tientsin, China and received his B.S. in mining and metallurgy in 1935 from there. He received his M.S. in mining in 1938 from Missouri School of Mines and an Sc.D. in metallurgy in 1945 from Massachusetts Institute of Technology. Mr. Sun has worked as assistant mining engineer in Shansi, China from 1935-36 and from 1938-42 had a research fellowship with U. S. Bureau of Mines. Mr. Sun was born in Shantung, China and is now residing in State College, Penna. where he is presently employed as assistant professor of mineral preparation by Pennsylvania State College. Among some of the papers which he has presented before AIME are: "The Mechanism of Slime Coating" and "The Frothability of Pine Oils". Playing tennis, cooking Chinese food and photography are Mr. Sun's favorite hobbies.

C. Y. Wang *(Tungsten, P. 853)* was born in Hong Kong, China and attended Pei-Yang University and Columbia University. He received a medallist from Columbia in 1929. Mr. Wang is at present director of research at Wah Chang Corp. in New York City. He has presented two other papers before the AIME—"Tayeh Iron Ore Deposits" and "Antimony Smelting in China". Mr. Wang's former positions included being superintendent of Tayeh Iron Mines and technical adviser to Liu Ho-Kow Mining Co. from 1918-1929. Mr. Wang's main interests are centered on tungsten and antimony. Mr. Wang holds membership in the Institute of Mining & Metallurgy in London, Mining and Metallurgy Society of America and is a member of AIME.

Oscar Weiss *(Contribution of Geophysical Surveys to the Discovery of Stilfontein Goldmine in Africa, P. 886)* was born in Hungary and attended the Technical University in Budapest. He was presented with a gold medal of the Chemical, Metallurgical & Mining Society for research in geophysics. Besides holding membership in AIME, Mr. Weiss also is a member of Institute of Mining & Metallurgy in London, Society of Exploration Geophysicists, and American Geophysical Union. He has done exploration work on gold deposits in the Union of South Africa and Gold Coast and has done exploration work for lead deposits in North West Africa, Tanganyika, Nigeria, Australia, and Newfoundland. His more recent positions include being geophysical consultant to the Dept. of Mines in the Union of South Africa and oil exploration work in Canada. Research of improvements in geophysical techniques is of particular interest to Mr. Weiss.

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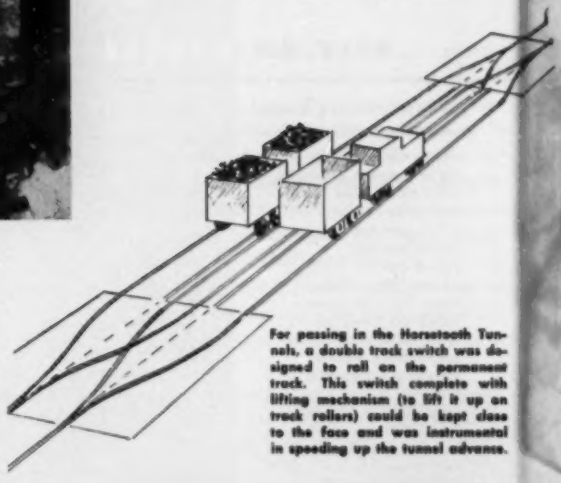

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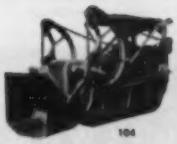

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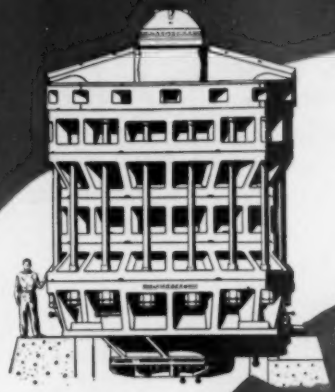

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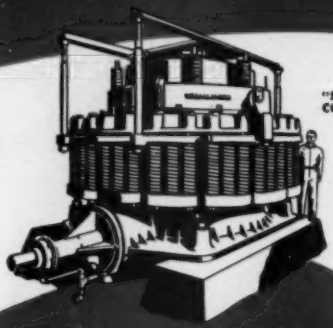

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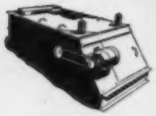

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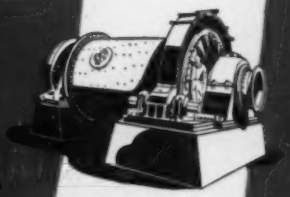

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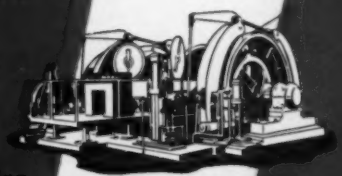
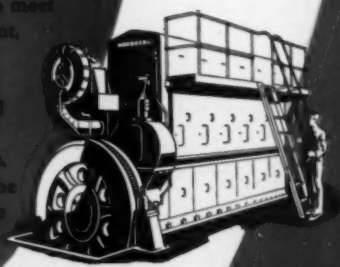


MINE HOISTS



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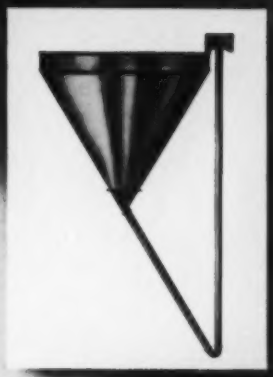

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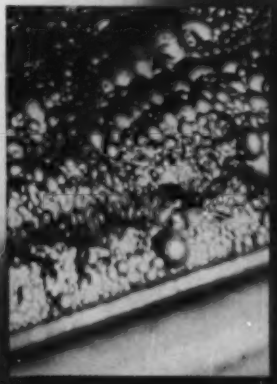

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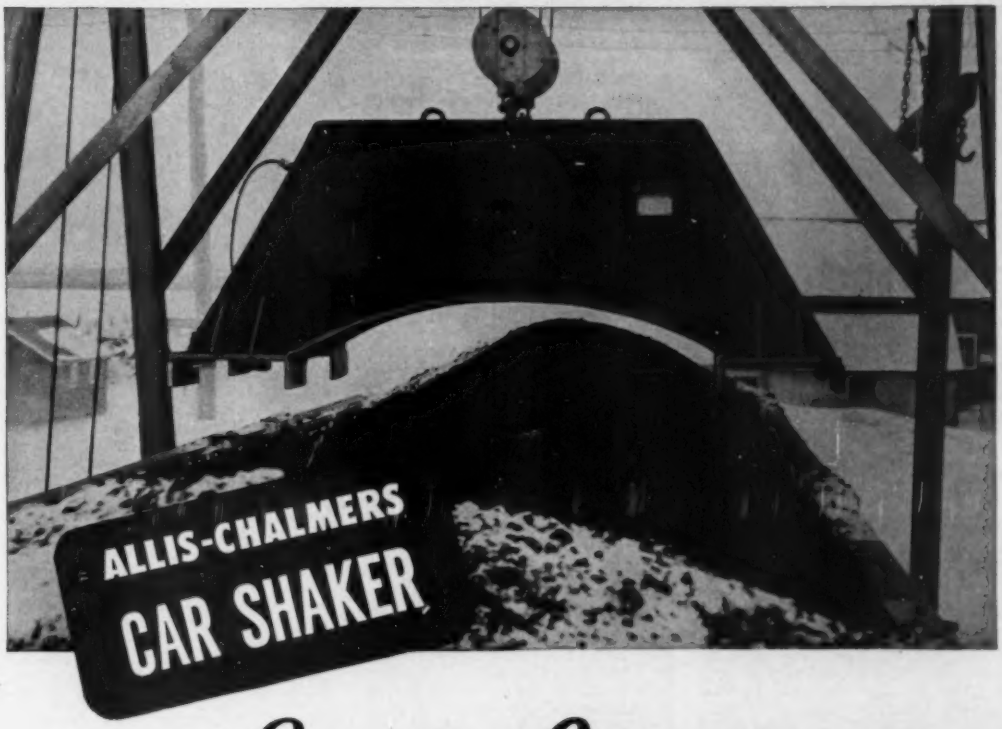

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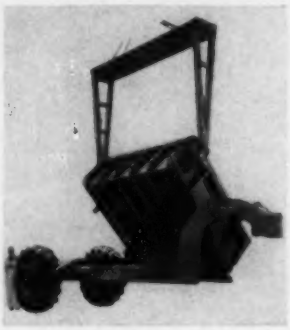
Side-Dump Trailers

Easton Car & Construction Co. of Easton, Pa., manufacturers of heavy duty off-highway truck bodies and trailers, are now building semi-trailers of gooseneck construction employing two Easton side-dump body designs. First of the new gooseneck trailers to be completed is



Model TL-1015, a lift door side-dump of 15-tons capacity. This unit is designed for service with the Caterpillar DW-10 Diesel tractor. The lift door body is designed for fixed point dumping, using the Easton electric overhead dumping system. The push-button controlled overhead hoist operates a dual hook which engages the two dumping bars on the lift door. The door is raised clear of the load, then serves as a bail to raise the body to the complete discharge angle. Body and trailer frame are of all-welded steel construction, with heavy box-section reinforcements throughout. The body floor is reinforced by an oak floor cushion and a replaceable steel liner plate. The trailer is equipped with Bendix-Westinghouse air brakes, and 21.00-25-20 ply rating tires. **Circle No. 1**

Nylon Bearing

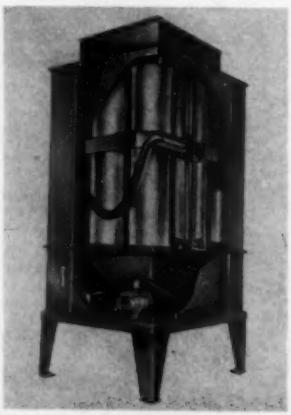
The du Pont Nylon FM10001 is a new bearing material. It is tough, resilient, and can stand temperatures in excess of 250°F and is unaffected by most ordinary industrial chemicals. The tough glazed surface which develops on nylon results in extremely low friction coefficients with a comparable low rate of wear. A typical Nylined bearing consists of an outer sleeve of inexpensive metal and a relatively thin lining of Nylon bearing material. The Nylon liner is retained in the outer sleeve in a manner which will permit it to expand and contract circumferentially around the inner periphery of the outer sleeve. Nylined bearings can be furnished in the plain sleeve type or the flange type. This product is available from *Thomas Industries, Inc.* **Circle No. 2**

Slide Rule

This slide rule, available from *J. L. Kerson* of Washington, D. C., is designed specifically for computations of decay factors and related data so frequently occurring in work with radioactive substances and isotopes. The slide rule consists of an outer frame and an inner portion movable with respect to the frame. There are three pairs of scales used as follows: Scales A and B are identical conventional logarithmic scales placed on the frame and on the inner portion respectively, and can be used for multiplication and division in the usual manner. The second pair of Scales C and D are laid off side by side on opposite sides of the same line on the inner portion of the slide rule. The third pair of Scales E and F, similar to C and D, is for the inverse computation of finding the correction factor. **Circle No. 3**

Dust Collector

Turner & Haws Engineering Co., builders of the Aeroturn dust collector has developed a self-adjusting blow ring. Each filter bag is circled by a self-adjusting blow ring which travels up and down the bag, flexing it slightly and directing the high pressure reverse-air-jet into the bag



from all sides. The flexing and the jet combine to dislodge dust which has accumulated on the inside of the bag. The dust drops down into the hopper by gravity and the downdraft of the incoming air. The self-adjusting blow rings hold the blow rings snugly in contact with the filter bag in spite of dimensional changes due to bag shrinkage or stretching. Each blow ring is made in two half-sections independently mounted on a common carrier assembly. The half-sections expand as necessary to conform to the bag's diameter as they travel the length of the bag, automatically adjusting to changes in the bag's diameter. A narrow slot milled in the inner periphery of each blow ring section contacts the bag surface and directs a high velocity air jet through the bagwall for maximum clearing effectiveness. **Circle No. 4**

Measuring Wheel

Rolatape Inc. announces the model 400 Rolatape, a measuring wheel which is exactly 4 ft in circumference and registers distance up to 100,000 ft then repeats cycle. It accurately measures and records as it is wheeled over course. The wheel does not sway in operation, but tends to stabilize its course and follow a straight line. This device has been extensively field tested and is being used in the coal strip and deep mining industry as well as metal open-pit mines. The model 400 weighs only 5 lb and is easily and efficiently operated by one man. The handle folds compactly so wheel can be easily carried and stored in the truck compartment. **Circle No. 5**

Jaw Crusher

Latest modification to the basic design of the A-1 jaw crusher is the dry rolling toggle, according to an announcement by *Allis-Chalmers Mfg. Co.* The change from sliding to rolling action is accomplished by reversing the curvatures of the conventional toggle ends and seats and making the difference in curvatures sufficiently great so that the cotangent of the acute angle formed by the line of force and a tangent line passing through the line of contact is less than the coefficient of friction during the full angular movement of the toggle plate. A special rubber apron is provided to keep material out of the toggle seats. The dry rolling toggle also incorporates a safety shear member on the portion between the pitman and the frame. To assure a rolling action between mating toggle ends, a high coefficient of friction is desired. Consequently, no lubrication is required, resulting in a substantial saving in the cost of lubricant. **Circle No. 6**

Free Literature

(7) BELT CONVEYOR IDLERS: Bulletin No. 51-81 on Rex belt conveyor idlers and machinery of *Chain Belt Co.* The book contains information on all of the latest designs and developments of this equipment. There are two pages of general engineering information to help in designing and specifying belt idler equipment. The very latest information on the new Rex Style No. 33RA return belt training (self-aligning) idler is given, together with material on the newly developed Styles No. 40 and 46 steep-angle troughed belt idlers. Latest data on lubrication material and techniques is included. A detailed description of zipper bunker seals is included plus data on belt conveyor trippers. A section of the book contains useful information on correct maintenance procedure.

(8) SHUTTLE CARS: The 370-371 car is equipped with three electric motors—two traction motors, each 7½ hp, and one 10 hp motor for driving two hydraulic pumps that power the steering, elevating discharge, conveyor and cable reel. Control is semi-magnetic with overload protection and a manually operated reverser. Acceleration of the car is automatic and is actuated by a two position foot switch for low or full speed by series or series parallel control. The frame of the car is a welded, one-piece unit reinforced with heavy cross members for added strength. The conveyor pan is made of high strength, low carbon content steel especially chosen for its qualities of strength and resistance to abrasion and atmospheric corrosion. Simplicity and convenience are features of the control compartment. Dual levers and switches are provided so that the operator may face in the direction of car travel at all times. This brochure is issued by *Goodman Mfg. Co.*

(9) TACHOMETER: Used for speed measuring applications where a particularly wide range of speed measurement is desired. Some of the favorable features are: Simple rotation of the range knob instantly selects one of three speed ranges to measure any speed over a total range of 40 or 50 to 1, based on readings down to 1/10 full scale of the lowest range. Indicating meter is of rugged design and in addition is mounted in sponge rubber. It is not damaged by currents up to 10 times full scale. With ordinary open wires, the indicator can be located up to 1000 ft from the head without materially affecting calibration. This booklet is published by the *Metron Instrument Co.*

(10) MAINTENANCE OF TRUCKS: *The Baker Raulang Co.* has just issued a booklet on the care and maintenance of industrial trucks. The first step in the weekly maintenance check is to blow all dust and dirt off truck with dry compressed air. Another step is the inspection of the chains and roller sprockets to see that sprockets roll free and that there is equal chain adjustment on chain anchors. Examining contactor tips for burning and wear is covered in fifteenth step which stresses to never file the contactor tips, as this is sure to change their shape and proper rolling action. Some transfer of metal is normal and if it does not interfere with proper sealing of the tips it should not be touched. This booklet covers 27 steps in the maintenance of industrial trucks and a picture is shown demonstrating the main points of each step.

(11) ENGINEERING IRONS SELECTION: A basic reference bulletin, compiled primarily for design engineers has just been released by *International Nickel Co.* This bulletin presents the many valuable characteristics of modern nickel cast irons. Twenty-seven useful tables, charts and photomicrographs show how through the use of nickel, alone or in combination with other alloying elements, the engineering properties of cast iron can be controlled to meet almost any reasonable combination of service requirements. Such topics as characteristics and applications of nickel cast irons, chemical composition and design factors are described in this booklet.

(12) SCRAPERS: Digging, hauling and spreading performance characteristics are presented in a new booklet recently issued by *Caterpillar Tractor Co.* This illustrated booklet tells about scraper design, haul features, dozer-type ejection on the fill, spreading, and open top bowl design for easy shovel loading. Some of the favorable features of scraper design include the stability to work in hilly country or on slopes, and small radius turning and maneuverability.

(13) DETACHABLE DRILL BIT: One of the outstanding features of Liddicoat bit is the pilot construction which chips the rock ahead of the cross-wings and eliminates the pulverizing action common with the conventional bit. The bit is attached to drill rod by lining up the flat surfaces of the rod end and the bit socket and slipping the bit on by hand pressure. Bits may be conveniently carried to and from the work on a simple wire carrier that can be made in any mine shop. The Liddicoat bit features two-stage cutting action which results in greater penetration per bit use and more footage per unit of time and money.

(14) CRANE AND YARD SHOVEL: A new catalog on their model 2000, 25 ton crane and 1¼ yd shovel has just been released by the *Manitowoc Engineering Works.* Twelve pages of details and photographs describe the machine and its advantages—including pictures showing how the Manitowoc plunger drum clutch operates, and how swing clutch linings can be replaced in a few minutes. New features explained for the first time are a new shovel crowd chain arrangement and a swivel type dragline fairlead. Individual diagrams show working ranges for crane, hoe, and standard and high lift shovel front end attachments. Crane capacity chart covers the full lifting range from 25 tons at 12 ft radius to 100 ft boom at 70 ft radius.

Mining Engineering **October**
29 West 39th St.
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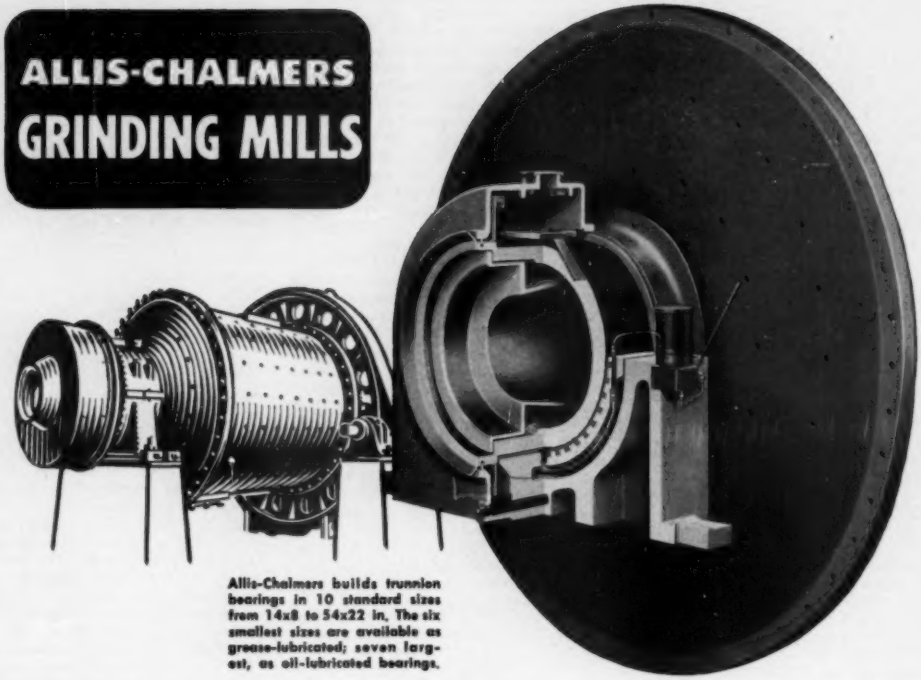
Trunnion Bearing Engineered to End Alignment Troubles

ALLIS-CHALMERS
GRINDING MILLS



Allis-Chalmers builds trunnion bearings in 10 standard sizes from 14x8 to 54x22 in. The six smallest sizes are available as grease-lubricated; seven largest, as oil-lubricated bearings.

BALL AND SOCKET design of this Allis-Chalmers trunnion bearing provides a spherical seat that corrects for *any* minor misalignment of mill and bearing. Load is always distributed evenly across the full face of the bearing.

A complete, self-enclosed oiling system is contained in the bearing housing. Soft babbitt cannot score polished trunnion surface.

Large oil-lubricated trunnion bearings are provided with a hand-operated lubricant pump for floating the mill prior to starting. This eliminates high starting torque, an important feature, since 75 percent of bearing wear occurs during initial starting after shut-down. Motor inrush current is decreased.

Allis-Chalmers builds trunnion bearings in lengths approximately one-half the diameter, in agreement with the latest engineering trend. Ample bearing area keeps bearing pressure low, prolongs bearing life.

The Allis-Chalmers representative in your area can give you more facts about bearings and other features of Allis-Chalmers grinding mills. Allis-Chalmers, Milwaukee 1, Wisconsin. A-3479

Pulverator is an Allis-Chalmers trademark.

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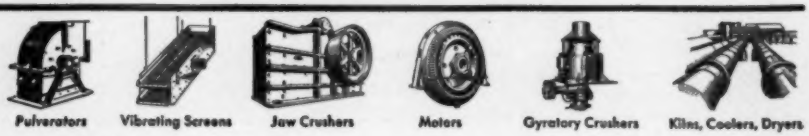

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Hornet Rock Drill

...and your miners can put more work on production

The H-22 Hornet is a terrific little rock drill. It weighs only 18 lbs., but it has all the design features found in larger Le Roi-CLEVELAND machines. That is why, pound for pound, you can't beat it for drilling speed.

And here's what your miners can do with it—easily and quickly, without strain: Drill holes for trolley hanger bolts. Clean up roof. Clear out rock falls. Brush bottom. Drill oversize pieces at the grizzly. Cut hitches. And a thousand and one other odd jobs.

Because the H-22 Hornet is so light, and drills so fast for its weight, your miners get these tasks done in a hurry — more time can be spent on production; your costs look better. So equip your miners with Le-Roi CLEVELAND Hornets. Complete information is available — just write for it.

H-22 HORNET FEATURES

- Weight — 18 lbs.
- Powerful blowing
- Strong rotation — easy holding
- Both wet and dry types
- Conventional rifle-bar rotation (3 pawls)
- Replaceable spacer bushing
- Spade or Tee handle
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Trends

BESIDES air—water, sulphur, salt, coal, and limestone are the key nonmetallic raw materials used by the chemical industry and each came in for attention at the AIME Industrial Minerals Division meeting at Morgantown, W. Va., Sept. 13 to 15. West Virginia is a growing chemical producing area with sites along the Ohio and Kanawka Rivers being favored because of power, accessibility of raw materials (many in the State), water supply, and transportation.

An estimated 500 billion tons of rock salt, enough for many generations to come, underlies northern West Virginia. This resource is tapped for the chemical industry by salt wells according to N. J. Ehlers of the Southern Alkali Corp. A water pipe is sunk to the top of the salt bed and a brine producing pipe is put down inside of the water pipe to just above the bottom of the producing formation. Hot water pumped down dissolves the salt, the brine being carried to the surface by the return pipe. In this area, wells are put down in pairs 700 ft apart. The salt is dissolved leaving an inverted conical opening which eventually merges with that of the adjoining wells. When two or more wells have joined in this manner it is possible to pump all the water down one well and obtain production from the others. The producer of artificial brine is beset with some problems however, in that roof collapse in the salt formation, movement of salt strata, and corrosion can stop production from a well.

In the South Charleston area there are large reserves of natural brines in the Pottsville formation which are described as fossilized sea water filling pour space in a sand formation. These brines are being produced commercially by pumping with deep-well and sucker-rod pumps from a depth of 1200 ft in the South Charleston area. The producing formations outcrop to the east and west of the brine producing area. Fresh water wells are pumping in the same formation on the flanks.

Coal and natural gas are also exploited as chemical raw materials in West Virginia. Listed among their important synthesis products are ammonia, urea, gasoline, resins, wood alcohol, lucite, and nylon. Although there is a tendency away from coal to natural gas according to Walter A. Koehler, head of the department of chemical engineering of West Virginia University, there will ultimately be a return to coal as a basic chemical raw material because of the vast reserves of it.

West Virginia does not have a water supply problem as far as abundance is concerned but there are technical ramifications in the procurement of industrial water supplies. R. J. Anderson of Battelle Memorial Institute listed the sources of industrial water as surface water, ground water, and artesian water. Surface water has the advantage of easy procurement in quantity but is subject to variable sediment content, temperature differential up to 48°F in a year, high acid or salt content, and high bacteria count. As opposed to surface water, ground water does not have many of the above limitations because of natural filtration and the alkalinity of host rocks and, according to Anderson, is more suitable for industrial purposes in northern West Virginia in the Ohio valley. The terraces along the Ohio River are particularly good industrial sites from the water standpoint because the gravels underlying the river banks at relatively shallow depths are productive of industrial water in adequate supply. Surface water in industrial areas, according to Anderson, will not be satisfactory for industrial use without treatment because regulations against contaminating industrial effluents, to be practical, set only maximum limits on contamination. As more plants are built, the concentration of contaminants will increase.

An all-out drive by free world nations to end the shortage of sulphur threatening the allied defense program was reported by J. C. Carrington, assistant to the president of Freeport Sulphur Co. He listed 46 projects, including 24 in the United States, to produce sulphur in different forms from various sources. These are expected to yield, on the basis of present estimates, approximately 3,000,000 long tons of the mineral by the end of 1953. Government sources have placed the world shortage of sulphur at 1,000,000 tons annually. "With defense production mounting, the sulphur shortage probably will get worse before it gets better." Large new additions to the supply include:

(1) Twenty four projects in the U.S. Four are new brimstone mines and one the expansion of an existing mine with a total anticipated new production of 1,200,000 long tons of sulphur. One of the new mines already is in operation. A second is scheduled to start production in the first half of 1952, another by the end of the same year, and the fourth, the newly discovered deposit at Garden Island Bay in Louisiana which Freeport will develop, by the end of 1953. Other projects are expected to add 350,000 tons of sulphur from natural gas, petroleum refinery gas, smelter gases, pyrites and low-grade surface deposits of sulphur.

(2) Seven projects in Canada and four in Mexico with an estimated new production of 500,000 tons of sulphur in all forms. A plant to mine sulphur by the Frasch process will be built at a salt dome deposit on the Mexican Isthmus of Tehuantepec.

(3) Expansion of pyrites production in Spain by increasing the annual rate of output at mines in Huelva Province by an amount estimated to be the equivalent of 400,000 long tons of sulphur. The Spanish mines have vast reserves, but production is now a little more than one half the prewar rate.

(4) Increases planned by Italy in the output of native sulphur amounting to about 250,000 tons yearly.

(5) Projects in Great Britain, Australia, Colombia, Japan, Norway, and Ecuador to obtain more sulphur in various forms from anhydrite, refinery gases, pyrites, and native deposits.

Carrington said free world sulphur production from all sources this year probably will exceed 1950 output of 10,700,000 long tons of which approximately 6,000,000 tons were contributed by the United States.

The United States has adequate reserves of lithium for many generations providing adequate concentrating capacity is provided. These and other interesting facts about this relatively rare metal came out in a paper presented by P. E. Landolt, vice president, Lithium Corp. of America. Mr. Landolt announced that Lithium Corp. was constructing a mill of 150 to 200 tons capacity which would concentrate lithium minerals (spodumene) by the flotation process. This new plant is being erected at Hill City, South Dakota. Gordon Chambers, vice president, Foote Mineral Co., mentioned that his company was starting this month to recover lithium by flotation at King's Mountain, North Carolina. The King's Mountain plant was operated by the Solvay Co. during World War II but although the plant produced at the average of 500 tons per month of 6 pct Li_2O concentrates, the operation was never economic. The average concentration of lithium in these ores is between 1 and 2 pct Li_2O.

Lithium is used in the ceramic industry to improve the bond between the metal base and the porcelain coating. Lithium is used to improve the effectiveness of lubricants; its halides are used for moisture absorption; small amounts are used to produce dense castings of copper and bronze; and it is used for the synthesis of Vitamin A. These are only a few of the uses of this metal which is slated for a big roll in the defense program.

IN the past few weeks Secretary Chapman has pointed up the mineral potential of the United States by reviewing the 1951 production picture with particular

reference to dependency on foreign sources in that year as compared with the average for 1935 to '39. The comparison is not favorable to the United States' present position. In another statement he said that the output of strategic and critical minerals and metals will show a notable increase during the next five years.

With reference to the "alarming decline" in the nation's self-sufficiency in many strategic and critical metals, the ratio of domestic mine production to consumption of 38 important minerals has been decreasing in the 6 years since the end of World War II. Estimates for 1951, compared with figures for the 1940 to '44 period, show that the nation has a lower self-sufficiency in 25 commodities, including such metals as copper, lead, zinc, and iron ore.

According to Bureau estimates for 1951 there are 9 commodities including sulphur, molybdenum, anthracite, bituminous coal and lignite, phosphate rock, salt, natural gas, helium, and manganese that the U. S. will produce in sufficient quantities to meet or exceed consumption demands for primary materials. In the 90 to 100 pct self-sufficiency class are nitrates, iron ore, and petroleum; ilmenite and potash in the 80 to 90 pct; and copper, zinc, rutile, and fluorspar in the 60 to 80 pct brackets.

There are seven strategic commodities for which there is virtual dependence on foreign sources including industrial diamonds, quartz crystals, tin, chromite, nickel, strategic mica, and long-fiber asbestos. The United States will produce a minute percentage of its tantalum requirements this year; 8 pct of the manganese needed in making steel; 9 pct of its mercury; 10 pct of its cobalt; 20 pct of flake graphite; 38 pct of bauxite; 55 pct of lead; and 26 pct of its antimony needs.

Taking a look at the production from new facilities, Secretary Chapman said that 8,991,600 tons of annual increased capacity of iron ore is expected which will accumulate to 17,438,900 tons by the end of 1955. Estimated increases in output are based on calculated production from 102 new facilities which have been certified by DPA to the Treasury Dept. Twenty one of these projects are expected to increase the annual production of copper, lead, and zinc by 40,900 tons, 35,700 tons, and 76,200 tons respectively; of antimony by 116 tons, and of cadmium by 309,000 lb.

There are 18 projects which when completed in 1955 will increase annual aluminum production by 476,350 tons, and similarly six alumina projects will yield 888,500 tons more. Bauxite production will be boosted 2,243,750 tons annually by 3 projects. Magnesium output is to be increased by 108 million lb a year and titanium to 8,436,000 lb by 6 other projects.

Tungsten output will be increased by an estimated 127,000 lb a year owing to two projects, and molybdenum output by 28,136,000 lb by three projects. Twenty seven projects will increase magnesite by 71,410 tons, lime and dolomite by 3,697,920 tons, calcined clay by 86,000 tons and fluorspar by 16,000 tons.

The following is a table of the cumulative increases for the 1951 to '55 period based on the 102 applications which have been acted upon. These expansion figures do not necessarily indicate a net expansion of the production of the various commodities as they do not take into consideration the exhaustion of present facilities.

Increased Production of Commodities by 1955 Based on 102 Contracts for Government Financial Aid

Iron ore	17,438,900 tons	Magnesium	370,000,000 lb
Copper	105,655 tons	Titanium	33,824,000 lb
Lead	116,890 tons	Molybdenum	98,262,000 lb
Zinc	256,180 tons	Tungsten	571,000 lb
Antimony	580 tons	Magnesite	322,850 tons
Cadmium	1,127,000 lb	Lime & Dolomite	16,898,970 tons
Aluminum	1,923,880 tons	Calcined Clay	344,000 tons
Alumina	3,237,500 tons	Fluorspar	66,000 tons
Bauxite	9,386,875 tons		

THE recent development in the metal cutting tool field of a device for machining by ultrasonic vibration should arouse some curiosity among drill manufacturers as to whether the method can be adapted to rock drilling. The new technique, known as the Cavitron process is used for cutting, threading, drilling, forming, and other machining operations on fully sintered cemented carbides and borides, stellites, hardened tool and die steels, and other hard and brittle materials such as glass, rubies, sapphires, and diamonds.

Unlike conventional machining methods, Cavitron employs a blunt tool in the shape of the cut or hole to be made in the work. It operates *head on* into the work by vibrating 27,000 times per sec. High vibrating frequencies impart to the tool accelerations in the order of 70,000 times the acceleration caused by the force of gravity. The actual cutting is done by a stream of inexpensive commercial abrasive, which is fed into the work area in a liquid carrier.

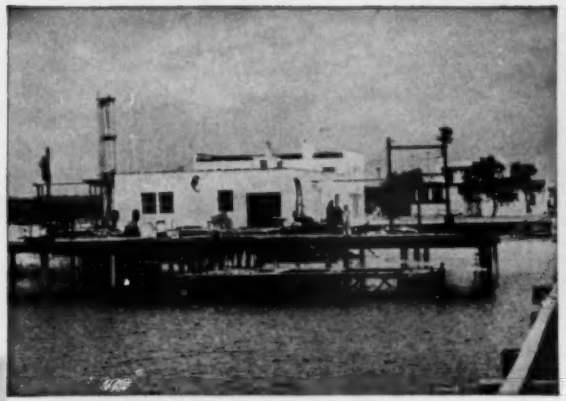
When the Cavitron machine is actuated the tool oscillates against the work while the liquid suspension of an abrasive such as boron carbide, is flowed over the work area. The extremely rapid tool vibrations hammer the abrasive particles against the work, causing myriads of chipping actions. The result is a smooth and rapid cutting into the hardest materials.

THE U. S. Geological Survey has recently devised techniques for geochemical prospecting which have been thoroughly tested on known ore deposits and in unknown areas and also are being used by the U. S. Bureau of Mines and some independent mining companies. The methods are applicable in areas where bedrock deposits are hidden beneath several hundred feet of soil or glacial debris because they utilize extremely sensitive chemical tests for traces of cobalt, copper, nickel, lead, silver, tungsten, molybdenum, zinc, and other elements to guide geologists in prospecting.

Tests show the trace concentrations to be high when near an ore vein in solid rock. The zones of abnormal metal content around mineral deposits are found in more or less oval-shaped ground patterns, called "haloes." The geochemist recognizes two basic kinds of haloe: (1) the primary, originating from the dispersion of metals in rock when the orebodies were formed, and (2) secondary haloes formed by the dispersion of metals in weathering processes. Secondary haloes are found in soil, plants, and ground water as well as in bedrock.

All equipment and chemicals used are inexpensive and easily transported. The processes are devised for speed, sensitivity and simplicity, so that inexperienced workers can be trained to map rapidly the surface distribution of valuable metals present in any given area by on-the-spot tests. Both conventional colorimetric and chromographic tests are used. In conventional colorimetric methods, colored solutions are obtained in which the intensity of the color provides a means of measuring the amount of metal present. The chromographic spot test, however, yields colored spots of definite size, and again the intensity of the final color is the means of measuring the amount of metal present.

The chromograph has proven useful for making quantitative spot tests for cobalt, copper, nickel, and silver in soil and rock, and for determining nickel in vegetation. With this device it is now possible to make copper or nickel tests anywhere and provide the analysis within a few hours time. The equipment needed is a "pocket type" gasoline stove, the chromograph, and a reagent box, all of which can be carried in a small suitcase.



View of Harbor Island Laboratory and Testing Station.

Lowering piling test specimens into place. Sea water is something more than a mixture of chemicals; its corrosive action over an extended period can be studied properly only by exposure of specimens to attack under natural conditions.

New testing station provides expanded facilities for corrosion studies

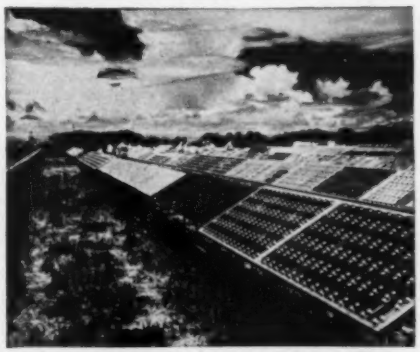
During the past 15 years, the Atlantic Ocean at Kure Beach served as a giant test tube for studying attacks of sea water and salt air upon more than 35,000 specimens, including virtually all types of metals and alloys.

Storm damage to the basin, in which the underwater tests were conducted, compelled establishment of a new and protected testing station. Accordingly, some 13 miles north, on Harbor Island, the new Inco Marine Laboratory was built to provide expanded facilities and an even better "Ocean Test Tube."

This new Harbor Island station, along with the atmospheric test racks retained on the shore of Kure Beach, now widen the scope of cooperative enterprise for fighting industry's common enemy — *corrosion.*

The vast amount of valuable data accumulated over the years will continue to be made available to all industry, as well as to government agencies for whom and with whose cooperation much of the research has been undertaken. You are invited to consult us on your corrosion problems.

Running water troughs. For studying the action of sea water flowing at moderate velocities, specimens are immersed in the troughs, shown above. The total length of trough used for this purpose now amounts to about 600 feet.



Atmospheric and spray test lot. Shown above is part of the atmospheric test lot at Kure Beach in which over 20,000 specimens have been exposed, some for over nine years. The racks face south, and the specimens, supported on porcelain insulators, are all set at a slope of 30 degrees.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

This month, Foote Mineral Co. will start to commercially recover tin in the area of Kings Mountain, North Carolina. For 50 years there have been intermittant efforts to recover it but it has finally become economic as a by-product in the mining and concentrating of the associated lithium ore.

An unusual deposit of a nonmetallic mineral which is high in sericite, low in quartzite, and similar in physical characteristics to pinite, has been discovered by the Summit Mining Corp. in Adams County, Pa. Work is in progress to determine its suitability for ceramics, fillers, and extenders for insecticides.

Resurrection Mining Co. at Leadville, Colo., has boosted production from the 10-yr. average of 5 tons per man-shift to 10 tons per man-shift by changing mining methods from square-set stoping to top slicing. B. B. Greenlee, assistant manager, is hopeful of improving the record this year by making a further change to a modified sublevel caving.

Some 55,000 tons of primary copper have been lost because of strikes since July 1. Copper now promises to be as serious a distribution problem as steel and allocation for consumer durables is expected to be curtailed.

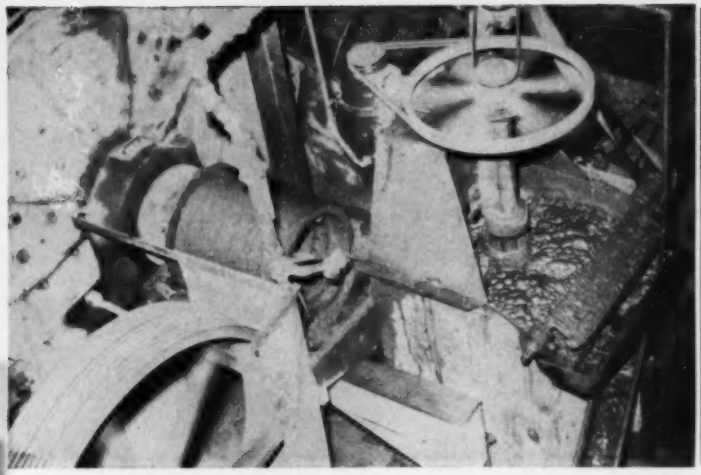
A total of 112 contracts involving expenditures of $7,496,469 have been executed between the Government and operators or lessees for mineral explorations since the program began last April. The Government is putting up about 59 pct of the money, while private industry the remainder.

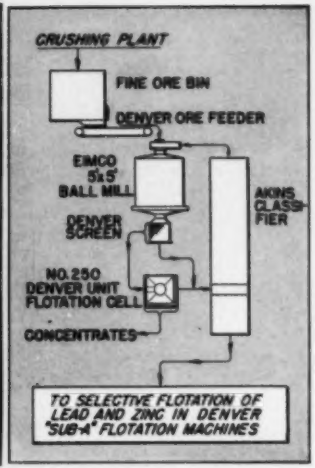
An ore carrier-tanker has been contracted for by a Norweigan shipping line. The vessel, scheduled for delivery early in 1954, will be almost unique in the field of naval architecture and marine engineering. The ship will transport ore from West Africa to Norway. When this trade slackens, it can be diverted to oil cargoes.

Nitric acid, which is comparatively abundant, can be used in place of scarce sulphuric acid in processing phosphate rock for use in commercial fertilizers, according to Eugene D. Crittenden, chief of research of the nitrogen section of the Solvay process division of Allied Chemical & Dye Corp.

Expansion of the Pacific Northwest's aluminum industry is planned, with increases in present plant capacities anticipated and erection of a new plant at Wenatchee, Wash., by Alcoa proposed. Oregon's high-iron bauxite reserves, owned by Alcoa, may come up for closer scrutiny.

DMA is not receiving any more applications for Government aid from producers and processors of limestone, fluxstone, dolomite, caustic lime, hydrated lime, dead burned dolomite, magnesite, periclase, and magnesium oxide as the supply of these commodities is sufficient to meet needs for the next 5 years.





How Silver Standard Mines Ltd.* Recovers 65% of Lead As Soon as Free... Using Denver "Sub-A" Unit Flotation Cell

HERE ARE THE FACTS

65% of total lead concentrate shipped is recovered in a No. 250 Denver "Sub-A" Unit Flotation Cell.

Unit Cell concentrate contains 55% of the silver and 68% of the lead recovered in the combined lead concentrates. In general, Unit Cell concentrate is considerably coarser and more easily filtered than that produced by lead cleaner cells.

FEED DENSITY RANGES FROM 55% TO 65% SOLIDS.

SCREEN ANALYSIS OF UNIT CELL FEED

	+48 mesh	35.5% by weight
—48	+65 mesh	15.7% " "
—65	+100 mesh	13.9% " "
—100	+200 mesh	14.7% " "
	—200 mesh	20.2% " "

ASSAYS:	Au	Ag	Pb	Zn
Mill feed	.10 oz.	45.0 oz.	5.0%	10.0%
Unit Cell Concentrate	.50 oz.	400 oz.	58%	9%
Pb Cleaner Concentrate	.70 oz.	600 oz.	50%	12%
Combined Pb Concentrate	.80 oz.	470 oz.	55%	10%

*Silver Standard Mines, Limited, New Hazelton, B. C., Canada

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Bulletin No. T4-B10, How to Schedule An Ore Test
Bulletin No. J2-B8, Denver Selective Mineral Jigs

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MINING
ENGINEERING

EDITORIAL

THE GREAT LEVELER

IT is certainly fitting and proper that the shortage of engineers should be the topic of frequent editorials in the professional magazine of mining engineers, but many of you are directly concerned with another shortage; namely, the shortage of skilled miners. It is often said that the military organization is built around the noncommissioned officer and it is similarly true that the mining organization depends for its production on the skilled miner—the NCO of the mining industry.

In the April 1949 issue of MINING ENGINEERING, J. K. Richardson referred to the shortage of miners as "The Mystery of the Missing Man." He advanced trenchant arguments for improved personnel policies that would attract miners from their wartime defense jobs back to the mines and also would encourage high school graduates to make their futures in the mining industry. The years since the war have seen great progress in progressive personnel policies but, even so, the skilled miner is becoming a "vanishing American." The crowning evidence of this was brought home to us recently when a crack tunnel boss remarked: "In my particular job, I need skilled men because each crew must be able to perform any part of the excavating cycle and the miners we've been hiring simply can't cut it." There was a time when this boss would have found miners better than trained tunnel men for such a cycle.

Richardson put his finger on a key point when he suggested emphasis by management on better housing, personal interest in the men and their families, and proper supervision as important in attracting men to work in the mining industry. However, the trend in unionism and industry-wide pay scales has had an adverse effect on the development of skilled miners. It has narrowed the differential between the compensation of the skilled man and the ordinary laborer. It has acted as a great leveler so that no longer is there that incentive which makes a man boast of the number of feet "pulled in a round." The miner-craftsman is becoming "the missing man."

We see no easy solution to this dilemma. Of course if union leaders would encourage the placement of a premium on production it would be a big step in the right direction. The other approach is to appeal to the pride of the individual in his work. After all, each man is eager for a respected place in the community. Public relations is a lever with which to restore the old respect for the miner. It should be directed toward the mining communities and those larger cities which are hubs of the mining industry. A skilled public relations program directed to this end would cause high school students to give some consideration to mining as a career.

The method of encouraging manpower for the mines of the nation is a job for specialists. Miners cannot be legislated into existence but trained personnel and public relations men can create incentives that will overcome the great leveling force of unionism.

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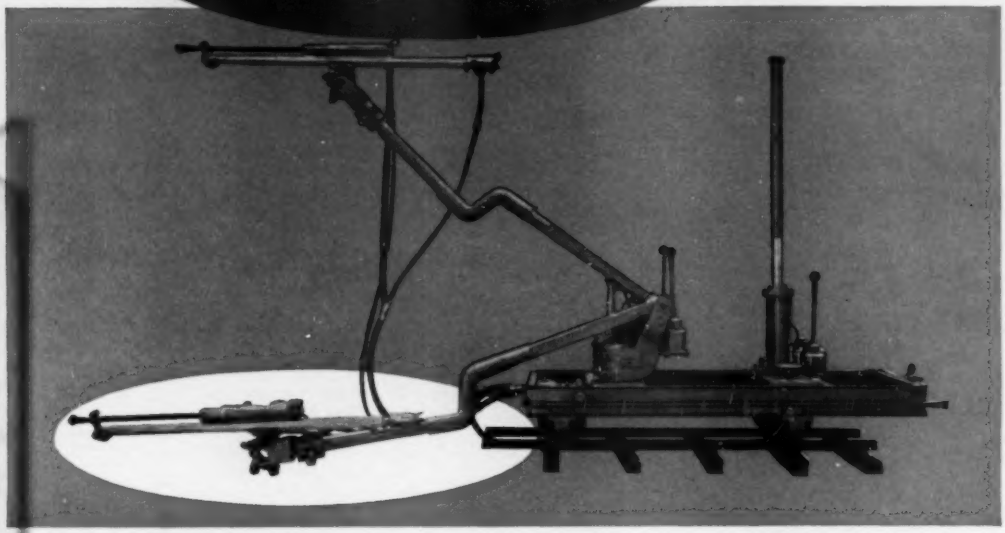

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MINING ENGINEERING presents the fourth in a series of articles on strategic minerals. Preceding it are "Cobalt" in January, "Sulphur" in May, and "Nickel" in August. Here, an authority in the field analyzes the resources, production, uses, defense impact and future outlook of - -

Need of Tungsten Is 'Desperate,' Senate Preparedness Unit Finds
WHILE U.S. STOCKPILING FALTERS
TUNGSTEN CORPORATION READIES
Canadian Tungsten Due Soon
250-Ton Mill On Tungsten Mine
To Give Canada Largest
Producer In North Americ
TUNGSTEN—Shortage Threatens Our Defense
To Develop Tungsten Facilities
LIMIT ON TUNGSTEN BUYING
Tungsten

by Chung Yu Wang

TUNGSTEN, although a minor element in view of the amounts used, is of major importance in today's technology. The development of high-speed steels, the electric light filament, and the tungsten-carbide cutting tools, rank with the greatest industrial achievements of all time. The United States has played a significant role in the application of tungsten to industry. In 1900, Taylor of the Bethlehem Steel Co. exhibited the use of tungsten-steel alloy as a high-speed tool steel, and in 1909, Coolidge of the General Electric Co. achieved the conversion of the most refractory metallic substance into a fine ductile wire. Consumption in the United States during recent years of about 33 pct of the world production of tungsten gives evidence to the role played by this metal, and the increasing applications and uses of tungsten and tungsten alloys. Because of the difficulty of maintaining a steady supply of tungsten ore—65 pct of the United States supply being imported—many attempts have been made to find substitutes. These have not to any appreciable extent diminished the strategic importance of tungsten to industry and the defense effort.

Uses

The chief use of tungsten is in the manufacture of ferrous tungsten alloys and tungsten carbide, the former accounting for about 90 pct and the latter for about 5 pct of the yearly consumption of tungsten in the United States. It is largely because of these ferrous tungsten alloys, which are predominantly tool steels, that great industrial advances have been made since the beginning of this century. Other smaller uses of tungsten are for the production of nonferrous alloys, electrical equipment, and tungsten compounds.

Other than high speed tool steels, to be described later, the ferrous alloy tool steels can be grouped as: 1—Oil hardening nondeforming steels; 2—Tungsten finishing steels; 3—Low alloy top steels; 4—Tungsten chisel steels; 5—Wortle die and self-hardening steels; 6—Die steels for hot work; 7—Die steels for cold work; and 8—Graphite steels. They are used for taps, reamers, chisels, broaches, bushings, gauges, dies, and punches. Altogether there are about 25 types of these tools. The properties that render these types adaptable for the particular kind of work to be done depend upon the amount of tungsten and chromium present in the steels, which in rare cases may contain small amounts of molybdenum, vanadium, or nickel. It is pertinent to mention that there are more than 200 different proprietary commercial tool alloys manufactured in the United States at the present time. They are for the most part protected by patents or by trademarks, and by variation of compositions cover a wide range of uses.

Of all the tungsten tool steels, the most important is the tungsten high-speed steel. The main characteristic of high-speed steel tools is that they maintain a sharp cutting edge at working temperatures far above those that ruin carbon-steel tools. This

CHUNG YU WANG is Director of Research for the Wah Chang Corp., New York.

General U. S. Imports, by Countries, of Tungsten, For First Six Months of 1951

Country	Lb Contained Tungsten
Australia	408,656
Belgian Congo	105,047
Bolivia	435,700
Brazil	441,482
Br. East Africa	19,096
Burma	75,255
China	26,384
Korea	15,810
Japan	47,720
Mexico	88,053
New Zealand	1,313
Peru	227,138
Portugal	71,971
Siam	298,370
Union South Africa	650
Total	2,262,645

property is generally known as red-hardness and develops at 700° to 800°C. The cause of red-hardness has not yet been explained satisfactorily.

A prominent mechanical engineer estimated that high-speed steel made possible the production in 5 days what otherwise would have required 6. The original type of high-speed steel is the so-called 18-4-1 type, containing 18 pct W, 4 pct Cr, and 1 pct V. There are now two principal representative types in common use; the tungsten types and the tungsten-cobalt types. Under the former are the 18-4-1, 18-4-2, 14-4-2, and 18-4-3 types; under the latter are the 18-4-1 plus 5 pct Co, 18-4-2 plus 8 pct Co, 18-4-2 plus 5 pct Co and 20-4-2 plus 12 pct Co types.

Ferrous alloys other than tool steels are the tungsten magnet steels and tungsten stainless and heat-resisting steels. Some tungsten magnet steels contain only few percentages of tungsten and chromium while others contain high percentages of cobalt, besides the usual percentage of tungsten and chromium. The tungsten stainless and heat-resisting steels are used for exhaust valves of aircraft engines, bolts and turbine parts, and distilling tubes in oil refineries. Their composition varies according to use. For example, the valve material contains 1 to 25 pct Ni in addition. There are about 100 different proprietary commercial ferrous alloys other than tool steels now manufactured in the United States.

Of the nonferrous alloys, Stellite, a cobalt-chromium-tungsten alloy, is the most important. As a cutting tool it was first placed on the market in 1913 by Haynes, its inventor. When iron is added to it, the resultant alloy is termed Festel metal. The various Haynes-Stellite alloys retain a higher hardness above 1100°F than the best high-speed steel. A typical form of Stellite has an approximate analysis of: 35 pct Co, 33 to 35 pct Cr, 10 pct W, and 1½ to 2 pct C. Because the alloys possess good resistance to corrosion and good wear resistance, they find use in equipment dealing with acids and other chemicals, excavating equipment, dies and punches, and shears for hot metals.

Copper-tungsten and silver-tungsten alloys are used as materials for switches, circuit breakers, and other switch-gear. The so-called *heavy metal* is a tungsten-nickel-copper alloy containing 3½ to 16½ pct Ni, 1½ to 13½ pct Cu, and 83 to 95 pct W. Because of its high density, it is largely used as material for radium containers, and rotors of gyroscopes.

Tungsten Carbide

This is indeed a carbide era. During World War II, the Germans were the first to use tungsten-carbide cores in high velocity armor-piercing projectiles. It was these tungsten projectiles more than Rommel that almost made Germany's North African campaign a success. Two years later, the United States Army perfected similar anti-tank projectiles which were used to stop Von Rundstedt's Belgian Bulge.

As production increases for the defense emergency, the use of carbides for the production of aircraft, shells, and tanks, assumes even greater importance. It has been said that 1 lb of tungsten carbide for cutting tools will do the work of 70 to 100 lb of tungsten in high-speed tool steel. Tungsten carbide tools containing 3 to 20 pct cobalt are used for cutting cast iron, nonferrous metals, and nonmetallics. The material is also used for dies for drawing and blanking, and wear resistant machine parts. Steel cutting tools are predominantly tungsten carbide, with either or both tantalum carbide and titanium carbide, and cobalt. Although tungsten carbide (WC) as a compound was prepared by Moissan as early as 1896, it was not until 1919 that Lohman made tool and die materials chiefly of this material. In 1927, Krupp patented a mixture of tungsten carbide cemented with up to 10 pct Co under the name of Widia, and this material is the basis of the modern tools.

Tungsten carbide has become an important material for rock drilling during recent years. It was in 1939 that the Germans first investigated its use for rock drilling. During the war years the Coromant line of drills, employing tungsten carbide, as developed by the Sandvick Steel Works Co. in Sweden, were used extensively in Sweden and Norway. Now, American carbide manufacturers in conjunction with rock-drill manufacturers have developed noteworthy tungsten carbide bits as well as having improved techniques for their use.

M. L. McCormack of the Ingersoll-Rand Co. gives the following advantages of carbide insert bits as against ordinary steel bits for rock drilling: 1—Drill 50 to 100 pct faster; 2—Increase production 20 pct or more; 3—Consume 30 pct less drill steel; 4—Save up to 30 pct on dynamite; 5—Reduce compressed air requirements at least 40 pct; 6—Reduce maintenance costs 20 to 65 pct; 7—Drill 50 to 400 times more hole footage per bit; 8—Permit use of lighter drills and longer steels; 9—Require less shop equipment; and 10—Save up to 50 pct in man hours.

Although the use of tungsten for the manufacture of filament wire, rods, contacts and other electrical uses is extremely important, this use represents only about 1 pct of the total annual consumption in the U. S. With regard to the manufacture of lamp filament, it is estimated that 1 lb of tungsten drawn into a wire 8.5 miles long, and 0.00183 in. diam provides filaments for 23,000 60-watt lamps.

Preliminary Data for First Half of 1951 on Tungsten, Short Tons of 60 Pct WO_3

Period, 1951	Production	Mine Shipments	Imports for Consumption	Consumption	Industrial Stocks at End of Period		
					Consumers and Dealers	Domestic Producers	Total
1st Quarter	1425	1332	436	3318	4379	378	4757
2nd Quarter	1823	1663	1633	3332	4302	238	4540

Fig. 1—Flowsheet for production of tungsten powder.

Phospho-tungstic acid in conjunction with phosphomolybdic acid is used in the preparation of lakes or pigments for the printing-ink industry. Sodium tungstate, mixed with a small amount of ammonium phosphate and ammonium sulphate, is used for flameproofing and water-proofing materials.

These multitudinous uses of tungsten—in the field of hard alloys and in the field of fabrication of armor plate, gun barrels, the cores of small arms and large-caliber armor-piercing projectiles—show clearly its utter importance in any war effort. Under present world tension and in preparation for an eventual emergency, the role tungsten has played in the past and is going to play in the future is evident. It is pertinent to mention that, according to Ralph C. Stuart of the Westinghouse Electric Co., tungsten was used in 15,000 different types of war items during World War II.

The imminence of possible shortage of tungsten under war conditions in the past has given impetus to metallurgical search for at least a partial substitute for tungsten. Since molybdenum has to a great extent the chemical and physical qualities of tungsten, it has been used in partial substitution for tungsten. A series of molybdenum-tungsten high-speed steels have been developed during recent years and are known to possess particular properties suitable to certain types of work. For instance, it has been reported that several large automobile companies in the United States have adopted a so-called molybdenum high-speed steel as a standard. Its representative compositions are: 0.80 pct C, 4.2 pct Cr, 5.0 pct Mo, 2.0 pct V, and 6.5 pct W. This steel is equal in some respects to the standard 18-4-1 type of high-speed tool steel. However, the toughness of this kind of steel is not comparable to those with high tungsten contents and the difficulties encountered in heat treatment of these steels are greater.

Beneficiation

Each type of tungsten deposit is a separate problem in the matter of selection of the proper method of concentration. Methods generally adopted for concentration of tungsten ores and for improvements of their concentrates are: gravity, flotation, magnetic, electrostatic, pneumatic, float and sink, roasting and leaching. The amenability to treatment of the ores or of their concentrates with respect to any of the methods or a combination of methods depends upon the types of ores or concentrates and their associated minerals and impurities.

Most tungsten deposits are of low grade. The lower limit of the grade of ore that can be concentrated profitably depends primarily upon the market value of the concentrate. For instance, 0.5 pct WO_3 ore may not be profitably concentrated if the unit price of the concentrate is $10 to $15 whereas at $20 to $25 it would be commercial. The great majority of the scheelite ores mined in the United States carry from 0.4 to 1.0 pct WO_3; the Bolivian ores, 2.0 and even as high as 5 pct; the Chinese ores, 1.0 to 3.0 pct; the Mawchi ores (Burma) 1.5 pct WO_3 and 2.0 pct Sn.

The aim of the beneficiation of tungsten ore is to produce a concentrate containing at least 60 pct WO_3 with impurities controlled to meet any particular requirements. The percentage of recovery varies with different classes of ore. For instance, with scheelite ore, using the usual gravity methods of concentration, 60 to 65 pct recovery is considered fair and an 80 pct recovery rather exceptional; with wolframite ore, an average 70 pct recovery is fair, 80 to 90 pct recovery exceptional. Attempts at a higher percentage recovery may yield a concentrate very much below 60 pct WO_3.

A typical plant for the treatment for semi-concentrates is the Wah Chang plant for concentrating tungsten. In this refining treatment major emphasis is placed upon the removal of impurities. The more detrimental impurities in tungsten concentrates are: sulphur, phosphorus, copper, tin, arsenic, antimony, bismuth, molybdenum, lead, tantalum and columbium. Silica and alumina are minor impurities.

The metallurgy of tungsten is unique in that, because its melting temperature (3410° plus or minus 20°C) is the highest of all known metals, it cannot be handled like ordinary metals. Hence, treatment of the ore for the production of metallic tungsten involves processes whereby intermediate products are first obtained. The usual intermediate product is tungstic acid. Metallic tungsten is then produced in powder form from treating this intermediate product, as shown in Fig. 1.

The use of sodium carbonate for fusion in a rotary furnace is generally adopted for wolframite ore. However, digestion with caustic soda under pressure would form an ideal process for the treatment of such ore. For scheelite ore, decomposition with acids, preferably hydrochloric acid is the usual practice. The most practical method of purifying the sodium tungstate obtained is to transform it to ammonium para-tungstate.

Most of the tungsten ores now produced go into the production of ferrotungsten which is used for the manufacture of tungsten tool steels. The aluminothermic, silico-thermic, and electric furnace methods are used for the manufacture of ferrotungsten.

For the manufacture of tungsten tool steel, the electric arc furnace or the coreless furnace methods have largely replaced the older crucible method. The charge is made up of steel scrap and ferrotungsten or tungsten concentrate. The general trend in recent years with regard to the form in which tungsten is introduced into steel is toward the increasing use of high-purity tungsten concentrates as against the decreasing use of ferrotungsten. This is evidenced from the following table:

	1945	1946
Total consumption in form of ferrotungsten, pct	50	35
Total consumption in form of high-purity tungsten concentrates, pct	13	28

The manufacture of cemented tungsten carbides is effected today by going through the following steps: 1—After ball-milling the tungsten powders with the necessary amount of lampblack to form WC, the mixture is heated for 2 to 3 hr at about 1500°C; 2—The milled carbide is ball-milled with cobalt in a steel bottle for a period up to 60 hr; 3—The ball-milled mixtures are pressed in molds with a pressure up to 30 tons per sq in.; 4—The molded articles are subjected to a prefiring treatment at between 800° and 1000°C for about 30 min; and 5—The shaped articles, packed in alumina, are finally sintered at 1400° to 1500°C for 30 to 60 min in a hydrogen atmosphere.

With regard to the manufacture of tungsten carbide the Wah Chang Corp. has recently introduced a process whereby the carbide is made direct from unpurified concentrates and tungsten bearing residues. The process eliminates the costly prepurification or refining of tungsten ores and allows their reduction and handling in a manner which cuts down much of the labor and time required by the present day tedious methods of extraction. To illustrate the nature of this process the following example is given in Patent No. 2,535,217 issued to K. C. Li and C. M. Dice. The ore and residue treated had the following analysis:

	WO_3	Sn	Fe	Cu	As	S	SiO_2	C
Ore, pct	51.27	3.3	15.45	0.29	0.23	0.70	5.65	—
Residue, pct	2.72	23.84	11.70	0.09	0.13	0.60	12.58	2.68

The charge was formed by mixing 100 parts by weight of tungsten oxide bearing material with 20 parts by weight of bituminous coal (about 12 pct ash). The tungsten oxide bearing material was a mixture of 66.7 pct by weight of the ore and 33 pct by weight of the residue. The charge was smelted for 4 hr at 2700°F. The resulting metallic alloy (tin-iron) was cooled, crushed, and leached in an aqueous solution of hydrochloric acid. The residual tungsten component was tungsten carbide (WC). It contained 85.61 pct of the available tungsten in the charge; the remainder of the tungsten values found in the leach liquors and slimes was recovered and recycled in the following smelting charge. The carbide thus produced contained only a trace of impurities such as phosphorus, copper, arsenic, tin, and iron.

Tungsten Resources

The glaring fact that the tungsten resources of China alone amount to four times those of the rest of the world put together should be noted. With regard to tungsten production in the different countries, the following figures are given as indicative of their potentiality in production: Taking Russia as a unit, China's potentiality is 90, Korea 4.3, the United States 4, Burma 4, Brazil 2.2, Bolivia 2, Tasmania 1, Portugal 1, Russia 1, and the rest of the world taken together 2.3.

During the 25-year period from 1913 to 1937, the United States produced 35.5 pct of its requirements while U.S. consumption amounted to 30 pct of the world production. Both in 1943, when the world tungsten production reached its highest mark in history, and in 1948 the United States consumed about 33 pct of world production. In 1943 China, Bolivia, Argentina and Brazil supplied about 90 pct of United States' imports; while in 1948 China, Korea, Bolivia and Brazil contributed about 80 pct of the total import. Generally speaking, both in time of war and in time of peace, taking 1943 as the norm for the former and 1948 for the latter, tungsten requirements in the United States were dependent on imports amounting to about 67 pct of consumption. Thus the United States only produced about 33 pct of requirements. Now that the sources of supply from China and Korea are cut off, and under the stimulus of higher prices for tungsten ores (at present $65 per unit of 60 pct WO_3, about 260 pct greater than the ruling price during 1942 to 1945), the sub-marginal tungsten mines of the United States can be re-opened to produce at least 40 pct of the U. S. requirements.

For the years 1946 to 1948, about 98 pct of the domestic production was obtained from Nevada, California, North Carolina, Colorado and Idaho (Idaho is becoming of less importance) while the other eight tungsten producing states produced only about 2 pct. China, Korea, Bolivia, and Brazil accounted for an average 65 pct of imports for consumption while the other 21 tungsten producing regions of the world, the balance. Domestic production contributed about 36 pct of the United States' total consumption.

During the present world situation the center of tungsten production for the "free world" has shifted from the East to the West. Whereas before the present communistic dominance of the Far East, China, Burma and the Malayan regions furnished about 60 pct of the world requirement, now their production for the "free world" requirement is negligible. The requirements of the present emergency have been met by production mostly from the United States, Bolivia, Brazil, Spain, Portugal, and Australasia. Under the stimulus of high prices, the domestic submarginal resources represent supplies up to 25 years, according to E. W. Pehrson of Bureau of Mines.

During recent months, with the elimination of Chinese and Korean tungsten ore from the world market, there has arisen a world-wide scramble for tungsten ore which has driven prices sky-high. To counteract this insupportable situation the International Materials Conference, recently convened in Washington, has adopted a scheme for allocation of tungsten ore on the basis of estimates of production and consumption submitted every three months by the producing and importing countries. The countries subscribing to the plan are Australia, Bolivia, Brazil, Chile, France, the Federal Republic of Germany, Portugal, Spain, Sweden, the United Kingdom and the United States.

The diversion of Chinese tungsten supplies to Russia is a serious loss to the United States. However, if the sea lanes from the other foreign sources of supply remain open and if the present high price for tungsten ore is maintained as a stimulus for submarginal production, the present serious shortage of tungsten will be overcome in a few years.

Longhole Drilling Raises Successful At Holden

by JOSEPH A. NEWMAN

THE first trial of longhole drilling of raises began in June 1949 at the Holden mine, Chelan Div., Howe Sound Co. The cost of this raise was about the same as the average cost of raising by normal methods which was sufficiently encouraging to give the method further trial. At Holden, the Noranda method of blasthole drilling is used except that percussion drills have replaced diamond drills for making blastholes in all but certain special situations. Two thirds of these holes are between 40 and 70 ft long.

In longhole drilling raises, standard longhole equipment is employed. This includes 4-in. Leyners on sliding cone shells, 1⅛-in. round sectionalized steel in 30 and 60-in. lengths, 1¼-in. lugged shank adapter steel, and independent water swivels. Holes are collared with 2½-in. conventional steel, and then completed with 2-in. tungsten-carbide bits.

At first, the preparatory step was to clean the floor and emplace concrete to a depth of 6 or 8 in. This gave a good surface on which to collar holes, but frequently rock directly below the concrete broke loose and fell down the hole while it was being drilled making the pulling of rods difficult. When it came to blasting, 3 or 4 blasts inevitably shattered the concrete necessitating its removal before further loading could be done. Now the established practice is to clean the floor thoroughly with a blowpipe.

On the driller's instruction sheet are given the length and inclination of the holes and the location of the collar of each hole with reference to two string lines. These lines are established 6 or 7 ft above the floor in which the holes will be collared. One string is set on the bearing of the raise and of the holes to be drilled; the other string is normal to the first string. Both are essentially horizontal.

Fig. 1 is a copy of an instruction sheet used for the drilling of a section of a hanging wall slot raise. The drawing shows the location of the holes in plan.

The Leyner is mounted either on a short arm attached to a 3½-in. single screw column or on a long cross-bar supported by two columns. The latter is preferred because it gives a more rigid mount and permits the drilling of several holes from one setup.

Holes are collared as per the instruction sheet with the 2½-in. conventional starters in order to save wear and tear on carbide inserts and to permit the use of casings. The casings used are 16 to 24-in. sections of reclaimed 2-in. pipe. When seated in place a casing should extend 2 or 3 in. above the collar of the hole. Casings help to keep pieces of rock from falling on the drill bit and prevent cuttings from returning to the hole. This latter precaution is necessary only when water and cuttings do not drain away from the collar to the hole.

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A plumb bob hung from the reference strings is an aid in locating the collar of a hole as well as getting the drill on the correct bearing. Before starting to drill with a carbide bit, the Leyner should be rechecked for line and grade. Minor corrections can still be made after the casing is seated.

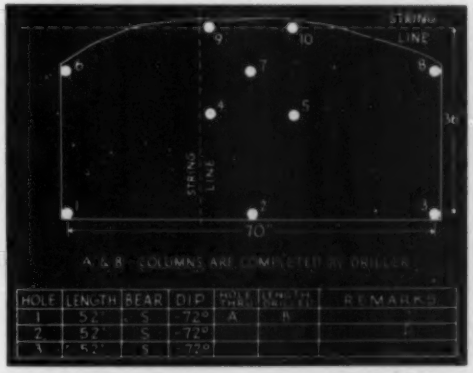
Fig. 2 shows the 10-hole pattern used for the drilling of 3 by 6-ft slot raises. Five of the holes make up the burn.

For 5 by 7-ft service raises 15 holes have been drilled as shown in Fig. 3. This pattern is not considered a standard one.

Where possible, the bottoms of the finished holes in a raise are plotted. This plot may show that one or more of the holes have too much burden at the bottom of the raise or it may show that the holes converge and the raise will be undersize when blasted. In either case, one, two or possibly more "extra" holes will be drilled. In order to direct these holes to the proper points and to avoid running into holes previously finished, the "extra" holes may be drilled on individual bearings and grades.

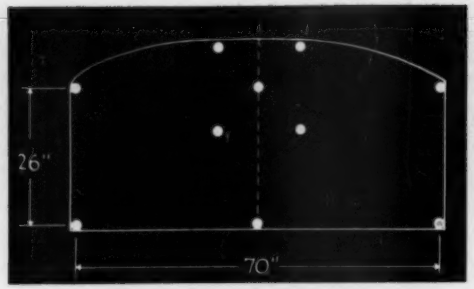
Fig. 4 is a view of a 54-ft section of the No. 4 (reference Table I) hanging wall slot raise looking parallel to the dip of the raise. The crosses indicate the bottoms of the holes in relation to the collars and they show divergence due to bending of the holes. The average amount of wander is about 21 in. Error in alignment at the start of the holes was minor. Two extra holes (marked by shading) were drilled to lessen excessive burden on other holes at the bottom of the raise. It will be noted that all 12 holes ran off course in the same general direction.

Most holes bend noticeably within 20 or 30 ft of their collars. In plots similar to the one shown in Fig. 4 this same tendency was evinced in two other raises



HOLE	LENGTH	BEAR	DIP	A	B	REMARKS
1	52'	S	-72°			
2	52'	S	-72°			
3	52'	S	-72°			

Fig. 1—Driller's instruction sheet gives him hole position, length, bearing, and dip. Columns A and B are completed by driller.



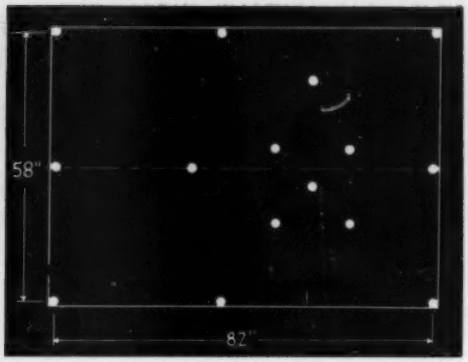


Fig. 2—A 5-hole burn is used in the 10-hole pattern in 3 by 6-ft slot raises (upper left).

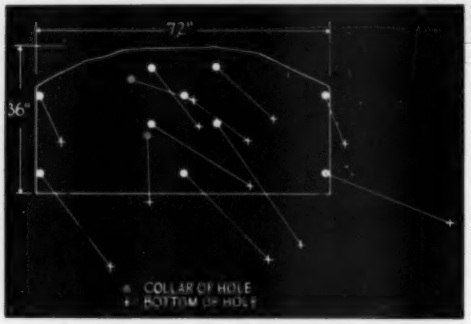


Fig. 3—For 5 by 7-ft service raises (shown above) 15 holes are used. This pattern is not standardized.

Fig. 4—Crosses indicate bottoms of holes in relation to their collars in drill pattern at left. Average wander is 21 in. for 54-ft depth of hole. Shaded holes are extra to relieve burden.

but in maps made of the holes in another two raises the absence of a common direction of wander was equally conspicuous. All five raises were driven in good drilling ground, but holes in these last two raises must have hit small irregular fractures, or even vugs, to cause them to run off courses in all directions.

For 58 holes drilled in the five raises mentioned above and ranging between 49 and 68 ft in length, the average amount of deviation due to both wander and misalignment was 21 in. This was an arithmetical mean and was irrespective of direction. Deviation of this magnitude is not excessively detrimental if the holes in a given raise all move off course in the same direction; where this is not the case additional holes are usually required. A maximum wander of 50 in. occurred in the drilling of one 68-ft hole.

For 7184 ft of longholes drilled in raises prior to August 1950, the footage drilled per man-shift was 53.9 ft; this rate has not changed much since that time. The average footage per man-shift for all 2-in. longhole drilling since it began was 67.5 ft. In one shift the maximum footage drilled in raises was 108 ft, while 152 ft was the maximum for ring drilling. Drilling of rings for ore breaking does not demand quite the same accuracy in alignment, casings are not needed in all of the holes, and more holes are drilled from one setup; these factors largely account for the faster daily rate of drilling in rings.

Before loading, holes are cleared of cuttings and rock fragments with a ½-in. blowpipe. For blasting, 1¾ by 12-in. sticks of 60 pct semi-gelatin dynamite are used. Previously 60 pct gelatin was used but the former seems to break the ground as well as did the more expensive gelatin. Occasionally, holes become constricted and powder in smaller stick size is required. Tamping of the explosive in the holes is done with jointed loading sticks. Detonation is by electric caps.

Sections of raise up to 10 ft in length have been loaded and blasted but 5 to 7-ft sections have proven to be the best lengths to blast at one time. Holes are blasted in a normal raise round sequence. The center burn hole is not loaded.

Where practical, loading for the first two or three lifts is done from the bottom. This permits better tamping of powder than is obtained by loading from the top of the raise. Also, it is desirable to have the loaders see just what and where they are loading.

In a hole which is open at the bottom, loading from the top necessitates a determination of its length. This is accomplished by lowering a weight through the hole with an observer at the bottom of the raise to signal by voice when the weight reaches the end of the hole. If the bottom of the raise is inaccessible, a wad of paper is shoved through the hole with the loading sticks. The point at which the paper falls free indicates the bottom of the hole.

To start the loading from the top, the first stick of powder is lowered on a light blasting wire the predetermined length to the end of the hole. This stick is anchored in position while other sticks are tamped against it. In each hole, all but the first stick and the one containing the electric cap are split and tamped individually.

If all of the holes are loaded and the holes maintain a good pattern throughout the length of the raise an advance of 6 ft or better is usual for the blasting of a 7-ft section. However, the average advance per blast has been between 4 and 5 ft. Even if the pattern is good, troubles do arise, usually as a result of not being able to load all of the holes.

When one or more holes bootleg it is likely that some of the adjacent holes will become constricted

or even partially fused. It may be impossible to open some of these holes by any reasonable means. Good advance cannot be expected on the next blast if some of the holes are not loaded sufficiently close to the bottom of the section. Broken ground or small faults cutting across the holes can be troublesome in blasting. Such a condition in the upper part of a section which is being blasted may result in a bench being left in the lower part of the section. If the bench extends across a large part of the raise, additional holes may be required to remove it before the next segment is blasted. In some places a small channel will be opened between adjacent holes above the section last blasted. Such an opening makes it difficult, if not impossible, to blow either of the holes clear of broken rock.

In one raise, the burn was drilled and an attempt was made to blast it before drilling the other holes. This was expected to minimize the chances of holes being constricted by successive blasts. After breaking out some 20 ft of the burn, the blasting became too tight and the advance was slow. The other holes in the raise were then drilled and blasted up to a point even with the burn. From there, progress continued with all holes being blasted in sequence.

In Table I are shown the unit costs of raises driven with longholes in comparison with the cost of normal raise mining. The average cost per foot of 960 ft of raises which were completed by longholing during the period of June 29, 1949 to April 1, 1951 was 79.8 pct of the unit cost of 1772 ft of untimbered raises which were driven in stope development work during the period of January 1, 1949 to April 1, 1951. These 1772 ft were completed by usual raising methods.

In raises which have been longholed, between 40 and 45 pct of the cost has been for drilling. Loading and blasting make up the other 55 or 60 pct of the expense. Nearly half of the drilling cost is for labor.

Most of the saving effected by the use of longholes in raises has been in slot raises which are of small section. Practically all of the untimbered raises other than the longhole raises are about 5 by 7 ft in section. Nevertheless, the above cost comparison is reasonably fair. Had not these slot raises been driven by longholing it would have been necessary to drive them approximately 5 by 7.

The No. 16 service raise is a long raise and the No. 17 service raise is in effect a continuation of a wing raise driven from a stope undercut. Had these raises been completed by usual methods, the unit cost for this work would have been considerably above the average of untimbered development raises. Before longhole equipment was used in the No. 16 service raise, the last 10 ft of advance cost 75 pct more per foot than the average figure. This was unusually expensive because efficient and skilled raise miners were not available.

Longhole drilling of the last 55 ft of the long No. 18 ventilation raise permitted its completion without any timbering which would have been necessary had it been finished by conventional means.

During times when skilled raise miners have been scarce needed development work has been accomplished by the adoption of longholing to the driving of raises. Aside from this aspect, this innovation has proven to be particularly advantageous in at least three types of situations. These are summarized as follows:

1—Driving of 3 by 6-ft slot raise between sublevels. This size usually serves as well as larger raises which would be driven in their place by normal raising.

2—Completing the top 50 or 60 ft of long and expensive raises.

3—Drilling raises into areas that are otherwise inaccessible.

Table I. Data on Longhole Raises

Raise Designation	Length, Ft	No. of Holes	Size, Ft	Pct of Standard Raising Costs
1	68	18	3 x 7	92.9
2	54	12	3 x 7	81.1
3	49	12	3 x 6	62.2
4	54	12	3 x 6	81.1
5	52	10	3 x 6	
6	52	10	3 x 6	70.6
7	52	11	3 x 6	
8	52	10	3 x 6	89.3
9	57	10	3 x 6	
10	53	12	3 x 6	58.3
11	60	13	3 x 6	73.8
12	55	10	3 x 6	58.1
13	34	16	5 x 7	164.0[a]
14	41	7	3 x 4	55.2[b]
15	33	12	3 x 6	67.5[c]
16	61	16	5 x 7	118.0[d]
17	63	15	5 x 7	143.0[e]
18	55	14	3 x 5	84.5

[a] Ground was badly broken; driller averaged only 44.1 ft per shift. One extra hole was drilled. Raise was drilled for length of 53 ft but longholes could be loaded and blasted for only 34 ft of advance.

[b] This cost figure is the average of 52 ft of longhole raise and 74 ft of standard 5 by 7 ft raise.

[c] This cost figure is the average of 41 ft of longhole raise and 66 ft of standard 5 by 7 ft raise.

[d] The top 61 ft of this 221-ft raise was completed with longholes. One extra hole was drilled; one hole could be loaded only 43 ft below the collar. Only the top 35 ft of raise broke well.

[e] Raise connected into top of a wing raise. After 11 ft of advance, several holes were closed 12 ft below the top of the raise. It was necessary to blast up to this point by loading from the bottom, access being through stope undercut.

Although longholes have been drilled up to 80 ft in length, 60 ft is considered a practical limit for drilling in raises. Distortion of the pattern of the holes is increasingly rapid as holes go to greater depths.

Presence of faulted and broken ground can and will preclude the use of longholes in raises. Even when the drilling is finished without too much trouble, completion of the raise is not insured. After two or three blasts, the rock around the holes may be so badly fractured that holes cannot be loaded for another blast.

Driving of raises by longhole drilling and blasting has proven its worth at Holden. Not only does the method alleviate the difficulty resulting from a scarcity of skilled raise miners, but use of the system in proper places effects appreciable savings in dollars and cents.

Acknowledgments

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In this aerial view of the operations of the Fresnillo Co. in the Mesa Central, the open-cut glory hole is at the back center, the tailing disposal area at the left, and the city of Fresnillo to the right.

MEXICO'S Metallic Ore Deposits

by T. P. CLENDENIN

THE northerly two thirds of Mexico falls into five main physiographic divisions, illustrated on the accompanying map. In form, these divisions are a series of strips, paralleling the northwest-southeast axis of the country.

Beginning on the east, the first division is the Gulf Coastal Plain. This is a typical, low-lying coastal plain, a continuation southward of the equivalent region of Texas, but growing progressively narrower.

Proceeding westward, the next division is a range or zone of mountains, rising abruptly from the coastal plain to elevations above 6000 ft, and known as the Sierra Madre Oriental. These are true complex mountains, and represent a southward continuation of the Rockies, coming down from the Big Bend country of Texas.

The next division is a broad table-land, ranging generally from 5000 to 7000 ft in elevation, and known as the Mesa Central. It is of typical basin-and-range topography, and is a close equivalent of the Great Basin of western United States, coming behind the Rockies.

The fourth division, known as the Sierra Madre Occidental or simply as the Sierra Madre, is a plateau built up of flat-lying lava flows. It is intensely dissected and rough, making a region of purest mountains in the layman's eyes, but actually the structure is almost undisturbed and it is a plateau in classification. Elevations of its peak portions usually range somewhat higher than those of the Mesa Central. It extends northward almost to the border, but has no real equivalent in the United States.

The final division, adjoining the Gulf of California, the Sonoran Peneplane, is a flat, low-lying region bordering the coast, but is not a coastal plain, but a complex area of older rocks worn down by erosion.

Gulf Coastal Plain—This division, like its counterpart in Texas, is composed mainly of young sediments, ranging in age from Tertiary down to the Upper Cretaceous, and affected by but little structural deformation.

From the standpoint of metals this division can be dismissed as of no importance. There have been a few small and random occurrences found within it, but nothing of any real significance. The oil deposits of Mexico all lie within it, at various localities along the coast, and it also contains the one important coal region of the country, centering around Rosita, in the northerly end of the area.

Sierra Madre Oriental—This division, the southward extension of the Rockies, is a zone of true mountains, of complexly folded and faulted structure. The rocks are mainly sediments. Lower Cretaceous and older in age. They are thus considerably older than the rocks of the coastal plain, but they occur much higher topographically, because of the uplift of the mountain belt. The mountains extend as a high, continuous wall along the inner edge of the plain, usually rising from it in a sharp escarpment.

In these mountains a number of mining districts have been opened, but they have been relatively small and have never ranked among the famous dis-

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tricts of Mexico. In character they are similar to the deposits of the more important Mesa Central. Some of the best-known districts in the division are Muzquiz, the Monterrey area, Dulces Nombres and Xichu, all of replacement type in limestone, and Teziutlin, a district of unique type in Mexico, with copper deposits in schist.

Mesa Central—The Mesa Central, as mentioned, is analogous to the Great Basin region in the United States, a wide upland area of basin-and-range topography. The rocks are dominantly sediments ranging in age from the Lower Cretaceous downward. The most prominent rock is a thick limestone series of the Lower Cretaceous, corresponding to the limestones of that age in Texas. This series forms most of the ranges through the area, and to a casual traveler may seem almost the only rock to be observed. Above and below it, however, are thick series of shale, which have eroded more readily and consequently form the valleys between the ranges. Also, at scattered localities rocks of greater age have been exposed, as for example sandstones, quartzites and limestones of the Paleozoic, in northeastern Chihuahua; graywackes and slates of undertermined age, around Zacatecas; schist, possibly Pre-Cambrian, at Catorce, etc. Finally, at many places the sediments have been cut by intrusive masses, usually between granite and diorite in composition. These are all relatively small, however, and never reach batholithic proportions.

This division contains many famous mining districts, and is the most important region of the country for base metals. The metals, as to relative importance, are zinc, lead, and silver in the first rank, with gold and copper in subordinate rank. The deposits are prevailingly zinc-lead sulphides, or their oxidized equivalent, but always with an important content of silver. Mexico is the leading silver-producing country in the world, and the metal is ubiquitous, appearing in practically every mine that is opened up, and frequently making mines on its own merits. Gold is of decidedly less consequence; it often accompanies the other metals in modest amount, but the values are seldom high, and it has made but few mines on its own account. Copper occupies a similar position, occurring in small amounts with other metals but having made few independent mines, either in this physiographic division or the others; and Mexico is not to be regarded as an important copper country.

The deposits of the division consist of three principal types. The commonest, and historically most important, is the replacement type in limestone. In Mexico this type shows certain characteristic habits, forming massive rather than disseminated occurrences, and taking the shape of pipes, either vertical or flat-lying to conform with the bedding, which are known respectively as chimneys and mantos. Sometimes the mineralization is localized close to intrusive rocks, sometimes not. The values are usually limited to zinc, lead, and silver. There have been literally hundreds of mines of this type, of all sizes, and at an earlier time, when they produced chiefly oxidized ores, they were the principal ores smelted, and served the important purpose of helping the smelting industry to become established in the country. Today the oxidized ores are largely exhausted and many of the mines have been abandoned, but some are still operating on sulphides.

Some of the most important districts of this type are the Santa Eulalia, often regarded as the classic example, Los Lamentos, Naica, Sierra Mojada, Ojuela, Reforma, Concepcion del Oro, San Pedro, and Zimapan. The Concepcion del Oro district has been notable for having, in addition to the normal lead-zinc type of mineralization, some excellent deposits of copper.

Map showing the five main physiographic divisions of Mexico also indicates mining camps.

In the Santa Eulalia district, Chihuahua, shown here, the operations of the Potosi mine of Howe Sound Co. and the Santa Eulalia unit of American Smelting & Refining are adjoining properties.

A night view of the Avalos mining unit of Compania Minera de Penoles, located at Avalos, State of Zacatecas.

These made the only important copper-mining operation that has ever been developed in the main body of Mexico, apart from the camps of Cananea and Nacozari up near the Arizona border, and Boleo in Baja California.

The second type of deposit consists of veins. These occasionally occur in the limestone, but much more commonly are found in the shale or other rocks of the division. The values generally include all five metals, with zinc, lead and silver predominating, gold and copper in subordinate place. Individual veins are apt to show considerable variation in values, however, more than in the case of replacement deposits; and in particular, veins carrying chiefly silver are common. On the whole, there have been fewer veins found than replacement deposits, and many of them have been small, but some have been most important. Of top note is the great district composed of Parral, Santa Barbara, and San Francisco del Oro, which has probably been the most important mining area of the entire country. Another great district is Fresnillo, and others worthy of mention have been Velardeña, Sombrerete, Zacatecas, Santa Maria de la Paz, Catorce, and the older portion of Charcas.

The final and least important type consists of contact-metamorphic deposits, formed where intrusive rocks have cut limestone. Most frequently these carry only copper, and are apt to be quite low-grade, but sometimes they carry zinc and a little lead, and then may be better in value. A good many examples of the type have been found in the area, but only a few have been of sufficient grade to be worked successfully, and these never of outstanding importance. Some principal working localities have been certain portions of Santa Eulalia, the Dolores district near Matehuala, and the newer portion of Charcas.

Sierra Madre Occidental—This, the Sierra Madre proper, is actually a lava plateau. It is built up of thousands of feet of beds of extrusive origin, of Tertiary age. The beds remain almost undisturbed structurally, to fulfill the plateau definition, but they have been highly dissected by erosion, and the topography is rough in the extreme. The individual beds are of many types, lava flows, tuffs, and agglomerates, often with water-laid beds intercalated among them, as conglomerate, sandstone, and occasionally even beds of limy character. In general, however, the lower part of the series tends to be andesitic, while the upper part grades into rhyolitic types. These rocks are younger and rest upon the rocks of the Mesa Central, and at the boundary between the two divisions the extrusives become thinner, and then disappear as a result of erosion. The boundary is ill-defined, however, and there are many erosional remnants or outliers of the extrusives to be found within the area considered as the Mesa Central. Toward the south, though, the extrusive area widens to cover more and more of the country, gradually overriding the adjoining physiographic divisions, until at the latitude of Mexico City only two are left, the extrusive area and the narrow strip of the Gulf Coastal Plain.

Mineralization in this division has been of just one principal type, veins carrying gold and silver values. The mineralization has been highly important, however, and has made this the great region of the country for precious metals, and it is a question whether, in the long run, this region or the Mesa Central has produced the greater wealth. As between the two metals, silver is ordinarily the more important, though veins better in gold content are not infrequent. Small amounts of base metals are often found in the veins, but are almost never of any real consequence.

There have been almost innumerable veins found in the area, large and small, and many famous camps developed. The greatest camps have been in the enlarged southerly end of the area. At the head of the list stands Pachuca, which has probably been the world's greatest silver district, and others are Guanajuato, Angangueo and El Oro, the last notable for having been the outstanding gold camp of Mexico. Many more camps existed in the extension of the area toward the north, however, which is the section properly called the Sierra Madre. Most of these are idle and half-forgotten today, because of the inaccessibility of the region, but they have an interesting historical significance, as the Spanish explorers made their way into this section and opened them up in early times, the region being easier for travel in those days, with its water and game, than the desert areas farther east. Some of the more famous districts were Pinos Altos, Ocampo, Batopilas, Guadalupe y Calvo, Guanacevi, Topia, and finally Tayoltita, which is still operating today.

Sonoran Peneplane—This low-lying area along the west coast is not a coastal plain, but an area leveled down by erosion. The rocks consist of an intrusion of granite of batholithic proportions, in which large masses of older rock remain, probably representing roof pendants. The granite is found over the greater

Shown here is the Charcas unit of American Smelting & Refining, San Luis Potosi, one of the famous mines of the Mesa Central.

Another one of the American Smelting & Refining operations is the Santa Barbara unit in the State of Chihuahua.

part of the area, and the remnants of older rock occur like islands within it. The older rocks consist of sediments probably ranging from Paleozoic to Cretaceous in age, and including limestones, quartzites and sandstones, slates and shales, etc. Patches of the Tertiary volcanics are also found, but whether these are older or younger than the granite is open to question.

Mineralization in the area is widely variable in both type and importance. A general rule seems to be that deposits of real value are almost never found in the granite, but only in the other rocks. At the northerly end of the area occur the two great copper districts of Cananea and Nacozari, which have made Mexico fairly important in the copper world. These districts can be considered, however, as an extension of the Arizona metallogenetic province, and not truly representative of Mexico, and without them Mexico is left with little in the way of copper resources. Through the remainder of the area, though, there have been no other occurrences of first-rate importance. There are a multitude of prospects, of all descriptions: veins, replacements and contact-metamorphics, some of base metals and some of precious metals; but they have proved only small to moderate in size. Some fairly successful mines have been opened up, but they have never reached great importance or fame, and do not warrant adding to the list of names. One significant point, however, is that attention in this area has been concentrated mainly on the precious metals, because of transportation difficulties, and that the base metals might show somewhat more importance when more work is done on them.

Southern Mexico—The outlines of the physiographic divisions, south of Mexico City, have not been shown on the map as details become obscure. Broadly, the coastal plain continues as a strip bordering the Gulf Coast, while the remainder of the country is occupied by the Tertiary volcanics. At many places, however, the volcanics have been eroded away, to expose island-like areas of the older rocks. These rocks are usually limestones and shales, probably Cretaceous like the limestone of the North, and a schist of some undetermined older age.

Mineralization occurs throughout the area, in both groups of rocks and varying in character accordingly, tending toward precious metals in the volcanics and base metals in the older rocks. It is less abundant than in the regions described to the North, however, and has not made districts of the same importance or fame. Among the leading districts are Zacualpan, Taxco, Campo Morado, Natividad and Taviche.

Peninsulas of Yucatan and Baja California—Yucatan is a low-lying area of Tertiary sediments, containing practically no mineralization. Baja California is composed of older rocks, and has had an important copper district at Boleo or Santa Rosalia, and an important manganese occurrence near-by. It has had a few other small mines at scattered localities, chiefly for gold, but none of them noteworthy.

Other Metals—The preceding discussion has been concerned entirely with the five main nonferrous metals, gold, silver, lead, copper and zinc. Mexico has a modest production of several other metals.

Iron is produced from a large deposit near the city of Durango, to supply the steel plant at Monterrey, and there are some important unexploited deposits along the Pacific coast, in Michoacan and Guerrero.

Tin has been produced at one of the mines in the Santa Eulalia district, in a remarkable association with lead and silver, making the only commercial tin mine ever worked in North America. Tin is also known in many small veins and placer accumulations through the states of Durango, Zacatecas and San Luis Potosi, but these have never been exploited on any serious scale, partly for lack of water.

Antimony has been produced at several localities, notably in San Luis Potosi, Durango and Oaxaca, but the deposits are usually rather small and erratic, and can only be worked by small-scale methods.

Mercury has been produced at many localities scattered all over the country, but it also is apt to be in small and erratic occurrences, suitable only for small-scale mining. An exceptional and interesting case was a large mine at Huitzuco, Guerrero, where mercury occurred in combination with antimony, as the mineral livingstonite.

Tungsten has been found at a number of localities in Sonora, usually in a contact-metamorphic setting, and is also known at a few places on the Mesa Central. It again is erratic, however, and its mining has nowhere become successful for that reason.

Manganese, lastly, occurs in deposits of small to moderate size at many places on the Mesa Central, and has made one rich deposit in Baja California, mentioned previously. These deposits were given little attention until the beginning of World War II, but since then have been worked with increasing activity.

Trucks Are Valuable Auxiliary Haulage Units in Rail Pits For:

(1) Making railroad grades
(2) Establishing benches
(3) Making new dropcuts

by G. J. BALLMER

WHEN discussing the subject of trucks for haulage, it is generally understood that they are used as prime movers and the mining system is built around them as haulage units. In open pits where railroads are used as main haulage, there has been little attempt to augment this rail haulage by trucks. This statement, on the face of it, is somewhat controversial, because Morenci was using trucks before the railroad was installed and continued them in service, particularly on the upper levels, after the installation of the railroad.

Experience with contractors at Chino indicated that a few trucks, enough to service one shovel, would be a convenient group of equipment to have in the pit. This has proved to be the case for they are extremely flexible in making railroad grades, in opening benches that could be opened by means of bulldozers, etc. Now they are being considered for the purpose of establishing new dropcuts. This type of truck haulage seems to offer vast possibilities and it is the purpose of this paper to point up some of these uses of trucks.

Establishing New Railroad Grades

From time to time new railroad grades must be established for the most efficient operation. This can occur either on the waste dumps or in the mine, on some of the benches. New grades on the dumps are perhaps more frequent. In the past this has been done with the equipment at hand. For dump grades the track would be laid, then waste trains would be dumped on both sides gradually raising the dump to grade and, after much work, the railroad grade would be built. With trucks, the grade could be staked out and the trucks allowed to use the grade as a dump and by the time the grade was built there would be a well-consolidated fill suitable for railroad track. The material for this grade could be obtained from any convenient bench not being restricted to shovels with railroad connections to furnish the material.

If a new grade in the pit is being made, it can be attacked with a shovel working to more or less final limits removing the material immediately rather than overcasting it, as frequently has to be done, thereby handling it twice. It seems certain that a great deal of money and time can be saved and a better job done by using truck haulage for establishing new grades.

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Opening Up Benches

Trucks can be used for opening benches in two ways. 1—For the re-establishment of old benches and 2—the opening of benches at both ends for through railroad traffic.

Bulldozers have been used several times at Chino for reopening old benches. This was possible because there was room for the spill or overcast. A similar project is now under consideration and room is not available to dispose of this material without loading it out and it would be extremely inconvenient to do the job with bulldozers. This job can be conveniently handled by a shovel loading into trucks behind it for haulage out of the pit.

Establishing Dropcuts

Establishing dropcuts with standard full-revolving shovels as used in the open-cut porphyries of the Southwest is generally a thought provoking experience. A drop of 6 or 7 ft at a time can be made and the track must then be shifted into the previous cut and the shovel started on a new cut. This procedure is repeated until the proper depth has been attained and the new bench established. The method of blasting for a dropcut of this sort is tedious and expensive. Much of the work is delayed pending the completion of certain types of drilling or the efficiency of the drilling and blasting is considerably impaired because there is only one open face to which to break. Wouldn't it be much more simple to layout the grade, the center line of the cut, drill to grade, blast, and start a shovel down on this grade, loading into trucks behind itself? In this manner a completed grade ready for track will be dug when the shovel gets to the other end of the cut. Also, all of the blasting is done to two open faces. These are some of the important things that can be accomplished by the use of a fleet of trucks and an extra shovel of sufficient capacity to keep the trucks rolling.

Destruction of Flotation Froth With Intense High-Frequency Sound

by Shiou-Chuan Sun

THE presence of an excessive amount of tough froth in the flotation of minerals, particularly coals, may create trouble in dewatering, filtering, and handling. Froth is also a nuisance in many chemical industries.[1] This paper presents a study on the destruction of extremely tough froths with intense high-frequency sound. The data indicate that sound waves can be employed for continuous and instantaneous defrothing. A powerful high-frequency siren was used in obtaining the data.

Also tested was an ultrasonorator of the crystal type with a frequency range of 400, 700, 1000, and 1500 kc per sec and a maximum power output from its amplifier of 198 w. The results, not presented, indicate that as now designed this machine is not suitable for defrothing. Although the sound generators of the magnetostriction type[2,3] and of the electromagnetic type[4,5] were not available, it is believed they are capable of producing the required sound intensity for defrothing.

The use of ultrasonics for defrothing was suggested by Ross and McBain[1] in 1944. Ramsey[6] reported in 1948 that E. H. Rose mentioned a supersonic device that broke down flotation froth but with low capacity. The writer has not been able to find any published literature containing practical experiments.

Theoretical Considerations

The mechanism of defrothing by sound is attributed to the periodically collapsing force of the propagated sound waves and the induced resonant vibration of the bubbles. The collapse of froth is further facilitated by the sonic wind and the heat of the siren.

Sound waves can exert a radiation pressure[7,8] against any obstacle upon which they impinge. When a froth surface is subjected to the periodic puncturing of sound waves, the bubbles are broken. According to Rayleigh[9] and Bergmann,[10] the radiation pressure of sound, P, in dynes per sq cm is given as:

$$P = \tfrac{1}{2}\ (\gamma + 1)\ \frac{i}{v}$$

where γ is the ratio of the specific heats of the medium through which sound is traveling and is equal to 1 on the basis of Boyle's law; i is the sound intensity in ergs per sec per sq cm, and v is the sound velocity in cm per sec. In this case, the accuracy of the formula is only approximate, because a perfect reflection can hardly result from a column of froth.

In addition to the radiation pressure, the propagated sound waves cause the bubbles of the froth to have a resonant vibration.[10] The vibratory motion of the bubbles causes collision and coalescence, thereby weakening if not breaking the bubble walls. Sonic wind and heat were also generated.[11] The sonic wind can exert pressure on the froth surface, and the heat can evaporate the moisture content of the bubble walls as well as expand the enclosed air.

Apparatus

The defrothing apparatus, shown in Figs. 1 and 2, consists of a powerful high-frequency siren, a glass or stainless steel beaker of 2-liter capacity with 12.4 cm diam and 17.1 cm height, and a metal reflector. The beaker was placed 2 in. above the top point of the siren. The metal reflector was adjusted to reflect and focus the generated sound waves into the central part of the beaker. Fig. 2 shows the crystal probe microphone used to measure the acoustic intensity and the mandler bacteriological filter employed to introduce compressed air into the beaker for frothing. The apparatus was enclosed in a soundproof cabinet equipped with a glass window.

The siren, shown in Fig. 3, consists of a rotor that interrupts the flow of air through the orifices in a stator. The rotor, a 6-in. diam disk with 100 equally spaced slots, is driven by a 2/3 hp, Dumore W2 motor at 133 rps. The frequency of the siren can be varied from 3 to 34 kc. The maximum chamber pressure is about 2 atm, yielding acoustic outputs of approximately 2 kw at an efficiency of about 20 pct. The siren itself is relatively small and can be operated in any orientation. A detailed description of the siren has been given by Allen and Rudnick.[11]

Collapse of Froth

To study the sequence of the collapse of froth, the glass beaker was partially filled with 920 cc water, 100 g of −150 mesh bituminous coal, 0.3 cc petroleum light oil, 0.2 cc pine oil and 1.54 cc Pyrene foam compound. This mineral pulp was agitated for 5 min and then aerated through a mandler filter until the empty space of the beaker, approximately 9 cm high, was filled completely with min-

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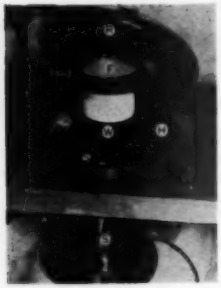

Fig. 1—Defrothing apparatus.

R—Metal reflector
F—Froth column
W—Liquid or mineral pulp
H—Horn of siren
S—Siren

Note that the froth was purposely prepared without the presence of mineral particles for the sake of better visualization in the picture.

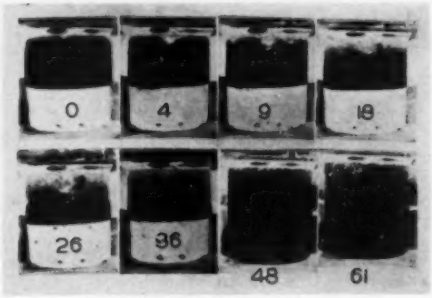

Fig. 4—Movie photographs showing the sequence of collapse of a highly mineralized froth column.

Note that the mineralized froth occurred only at the very black portion of the photographs; above that the less black portion was caused by the dissipation of the broken bubble fragments in air or by the attachment of these fragments on the inner surface of the glass beaker.

eralized froth. The siren was set at a frequency of 7 kc per sec, and a chamber pressure of 30 psi was maintained. The sequence of the collapse of froth was photographed with a Cine-Kodak Special, 16 mm motion picture camera at a speed of 16 frames per sec. The result of this study is shown in Fig. 4.

In Fig. 4, frame 0 shows that the froth was highly mineralized (in air the froth could persist for 4 hr). Frame 4 shows that when the froth column was exposed to the sound waves for ¼ sec, a round hole approximately 2 cm diam and 2 cm deep was punctured in the top. Frames 9 and 18 show that, after ½ sec and more, the bubbles vibrated violently. The longitudinal bubble waves with crest and troughs suggest the presence of resonant vibrations. Frames 26 and 36 show broken fragments, chiefly coal particles and water droplets, being dissipated into air at a maximum height of approximately 2 in. This may be caused by the force of 1—the sound waves reflected back from the froth, 2—the released air pressure from the broken bubbles, and 3—the vibratory motion of the bubbles.[10] The vertical black lines and dark color in the liquid phase of frames 48 and 61 indicates that the froth column was completely destroyed and the once floated coal particles fell back into the liquid. Approximately 4 sec were required to collapse the froth column.

Rate of Defrothing

A highly mineralized froth, prepared by the same procedure, was tested with different frequencies at a chamber pressure of 30 psi. The results, as plotted in curve 1 of Fig. 5, show that the rate of defrothing increases with the decrease of the frequency up to 6 kc per sec. This may be because the power output of the siren within certain limits is increased by the decrease of frequency, as shown in curve 2 of Fig. 5. The data of curve 2 were established by Allen and Rudnick[11] at a constant chamber pressure of 2.94 psi.

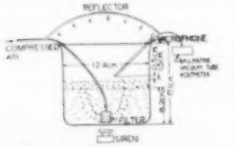

Fig. 2—Schematic diagram of the defrothing apparatus.

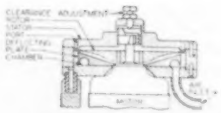

Fig. 3—Cross-section of the siren.

Froth Elimination

The prevention of froth on liquid surface by intense high-frequency sound was tested and proved satisfactory. The apparatus was set up as shown in Fig. 2; the beaker was filled with 920 cc water, 0.3 cc petroleum light oil, 0.2 cc pine oil, and 1.54 cc Pyrene foam compound and was agitated for 5 min. Compressed air was forced through a mandler filter, which was kept in the liquid during the entire testing period. One second after the mandler filter was introduced into the beaker, the chamber pressure and the frequency of the siren were varied simultaneously to form different combinations for the elimination of froth on the liquid surface. The results of the test are given in Table I.

Table I indicates that frothing can be prevented by bombarding the pulp surface with suitable sound waves. For the generation of a constant sound intensity, the relationship existing between the chamber pressure and the frequency of the siren is a straight line, as shown in Fig. 6.

Mathematically, this can be expressed as:

$$y = k + mx$$

Where y is the ordinate representing the chamber pressure in psi, k is the ordinate intercept at 0 abscissa, x is abscissa representing the sound frequency in kc per sec, and m is the slope of the curve.

Industrial Defrothing

The noise of the siren would be objectionable in its industrial application for defrothing. This could

Table I. The Prevention of Frothing on Liquid Surface

Test No.	Frothability of Solution with a Mandler Filter, Cm per Sec	Observed Height of Froth, Cm	Siren			
			Chamber Pressure, Psi	Frequency, Kc per Sec	Sound Intensity	
					W per Cm²	Balanline Decibels[a]
1	0.07	0.07	none	none	none	none
2	0.07	none	11	6.0	0.03	24
3	0.07	none	22	8.8	0.00	25
4	0.07	none	25	10.3	0.06	25

[a] Decibels relative to 1 mv.

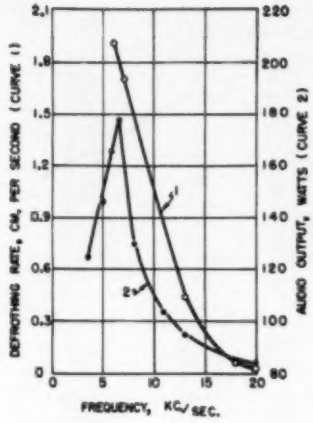

Fig. 5—Effect of sound frequency on the rate of defrothing and on the power output of the siren.

be remedied by enclosing both the siren and the upper part of the container in a soundproof cabinet, as shown in Fig. 7. The walls and ceiling of the cabinet can be constructed with wood or steel. Based on the experience of laboratory operation of the siren, the inner wall surfaces of the cabinet should be lined with a 6-in. thickness of cotton or other suitable sound-absorbing materials. At one side of the cabinet a door with one or two glass windows is provided for observation and accessibility.

Fig. 7 shows a few possible arrangements for industrial defrothing. The siren should be supported so that its elevation and horizontal position can be adjusted easily. Diagram 1 of Fig. 7 is a cylindrical container suitable only for intermittent defrothing of small-scale operations. Diagram 2 shows a rectangular or cylindrical container, capable of continuous defrothing of a medium size operation. Diagram 3 shows a launder for continuous defrothing.

Summary

1—A tough froth column can be destroyed instantaneously by means of a powerful high-frequency siren.

2—The surface of a highly frothable liquid can be kept free of froth by bombarding it with suitable sound waves.

3—For a given chamber pressure of 30 psi, the optimum frequency of defrothing for the particular siren used is about 6 kc per sec.

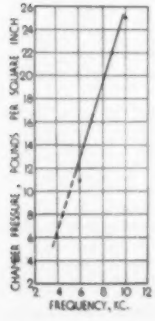

Fig. 6—Relationship between chamber pressure and frequency for the siren to produce a constant sound intensity.

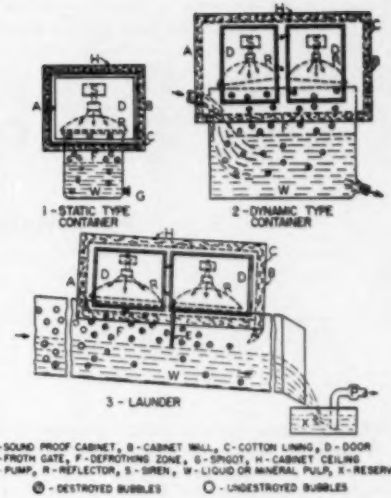
1 - STATIC TYPE CONTAINER
2 - DYNAMIC TYPE CONTAINER
3 - LAUNDER
A - SOUND PROOF CABINET, B - CABINET WALL, C - COTTON LINING, D - DOOR
E - FROTH GATE, F - DEFROTHING ZONE, G - SPIGOT, H - CABINET CEILING
P - PUMP, R - REFLECTOR, S - SIREN, W - LIQUID OR MINERAL PULP, X - RESERVOIR
- DESTROYED BUBBLES
- UNDESTROYED BUBBLES

Fig. 7—Some of the possible arrangements for industrial defrothing.

Acknowledgments

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Filter Cake Size-Consist And Moisture Relationships

by Orville R. Lyons

THE continuous vacuum filter, whether it be a vertical or horizontal disk, inside or outside drum, when properly applied is a very effective device for dewatering fine solids. Because of the number of variables that affect its performance, however, it is not possible to obtain consistently maximum moisture reduction in an operating plant. This paper presents a method for determining the average cake moisture and the variations in cake moisture to be anticipated when dewatering fine solids by continuous vacuum filters under normal operating conditions.

Previous investigators[1-3] have found that certain factors influence filter performance, drum or disk diameter, speed of rotation, percentage of immersion, and the percentage of solids in the feed influence capacity. Blinding of the filter cloth reduces effective vacuum, produces a wetter cake, and may decrease capacity. Reduced vacuum or improper adjustment between vacuum and blowing portions of the cycle will produce a wetter cake and also may decrease capacity. Widely fluctuating feed tonnages will adversely affect cake moisture and capacity. Flocculation, when properly applied, increases capacity and reduces cake moisture. Without flocculation, the slimes are the first particles sucked to the filter medium, which becomes partially blinded in consequence. With flocculation, the flocs act as coarse particles and the filter medium is not blinded. Overflocculated pulps, although filtering well, may yield wet cakes.

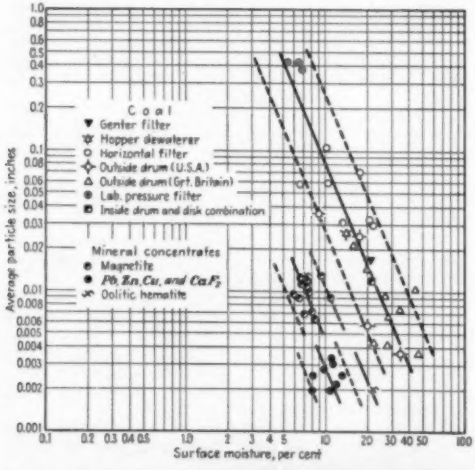

Fig. 1—Relationship between average particle size and moisture content of cake when dewatering coal and mineral concentrates by means of filters.

Average Particle Size and Cake Moisture

A method for predetermining the surface moisture content of coal filter cakes was published in 1949,[4] but this method could not be applied to coals deficient in −200 mesh material or to fine mineral concentrates.

Test data obtained for geared-weight types of vibrating screens[4] and for centrifuges[5] used to dewater coal provided definite correlations between the average particle size of a dewatered cake and the surface moisture content of the cake. It was thought that this same method of correlation should be applicable to filters, whether dewatering fine coal or fine mineral concentrates.

To develop a correlation or correlations between average size of cake and cake moisture, the author collected data for filtration operations from as many sources as possible. In a considerable number of instances the information was provided by plant preparation engineers,[6-9] a few of the tests were on a laboratory scale,[6] and the remainder of the data was obtained from published articles.[10-17]

Table I contains size-consist and miscellaneous data for coal filter cakes, and Table II contains the same data for mineral concentrate filter cakes. Fig. 1 shows the relationships existing between the average particle size of the cake and cake moisture (surface moisture for coal and total moisture for minerals) when dewatering fine solids by a variety of makes and types of filters.

Average particle size is calculated by averaging the linear openings of the various pairs of screens used in the screening test, weighted in accordance with the percentages of material in the various fractions.

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Table I. Size-Consist and Miscellaneous Data for Various Coal Filter Cakes

Mesh Size	Test No. 1 Wt, Pct	Test No. 2 Wt, Pct	Test No. 3 Wt, Pct	Test No. 4 Wt, Pct	Test No. 5 Wt, Pct	Test No. 6 Wt, Pct	Test No. 7 Wt, Pct	Mesh Size	Test No. 8 Wt, Pct	Test No. 9 Wt, Pct
4	0.8		0.4		11.2	1.7	21.7	+48	6.0	2.0
4 x 6	4.3	1.1	1.6	0.9	11.0	3.9	14.7	48 x 100	31.0	7.5
6 x 8	17.2	6.0	6.8	6.1	11.4	14.1	14.5	100 x 200	29.0	15.0
8 x 10	16.0	8.6	8.7	8.9	9.8	15.3	10.7	−200	34.0	75.3
10 x 20	23.8	19.8	12.8	16.2	13.0	22.4	13.5			
20 x 28	9.8	10.2	7.7	9.9	5.2	8.9	4.6			
28 x 48	13.4	12.4	15.6	15.4	7.5	16.4	9.7			
48 x 65	4.8	4.8	7.7	5.5	3.8	7.5	4.4			
65 x 100	3.4	6.7	7.7	6.7	4.2	5.1	3.1			
100 x 200	2.3	10.2	10.7	9.6	6.8	2.5	1.7			
−200	2.4	20.2	20.3	19.8	16.1	2.2	1.4			
Average cake size, in.	0.0586	0.0319	0.0314	0.0307	0.0729	0.0584	0.1054		0.0037	0.0038
Surface moisture of cake, pct	6.5	13.6	20.5	21.1	17.8	10.2	10.3		20.3	35.2
Type of filter	a	a	a	a	a	a	a		b	b
Coal seam	c	c	c	c	e	c	c		d	d

Mesh Size	Test No. 10 Wt, Pct	Test No. 11 Wt, Pct	Test No. 12 Wt, Pct	Test No. 13 Wt, Pct	Test No. 14 Wt, Pct	Test No. 15 Wt, Pct	Test No. 16 Wt, Pct	Test No. 17 Wt, Pct	Test No. 18 Wt, Pct
1/16 in. x 32	40.2	23.6		9.8	0.6	5.8	4.5	12.5	
32 x 60	19.3	16.1	5.7	19.5	1.7	5.6	17.6	16.6	1.8
60 x 100	22.0	15.2	8.6	9.6	4.9	8.6	9.6	12.6	5.4
100 x 200	12.5	21.6	27.2	11.8	29.1	19.6	14.8	20.8	14.4
−200	7.0	23.5	58.5	49.2	63.7	60.4	53.5	37.5	78.4
Average cake size, in.	0.0219		0.0045	0.0096	0.0042	0.0066	0.0075	0.0107	0.0037
Surface moisture of cake, pct	16.0	0.0150 19.8	23.0	26.9	28.0	25.7	34.3	45.7	47.8
Type of filter	b	b	b	b	b	b	b	b	b
Coal seam	e	e	c	e	e	c	c	e	e

Mesh Size	Test No. 19 Wt, Pct	Mesh Size	Test No. 20 Wt, Pct	Test No. 21 Wt, Pct	Mesh Size	Test No. 22 Wt, Pct	Test No. 23 Wt, Pct	Mesh Size	Test No. 24 Wt, Pct
10 x 14	19.0	8 x 14	8.3	29.1	¾ in. x ⅛ in.	26.9	26.9	¾ in. x ¼ in.	34.8
14 x 28	32.5	14 x 28	33.4	30.1	⅛ in. x 3	53.7	53.7	⅛ in x 3	49.7
28 x 32	5.5	28 x 48	30.3	18.9	3 x 6	9.7	9.7	3 x 6	9.5
32 x 60	17.0	48 x 100	15.4	12.4	6 x 10	9.7	9.7	6 x 10	9.0
60 x 115	11.8	100 x 200	7.4	4.5				10 x 28	5.0
115 x 250	5.7	−200	5.2	4.0				28 x 35	2.5
−250	8.5								
Average cake size, in.	0.0287		0.0244	0.0355		0.4018	0.4018		0.3744
Surface moisture of cake, pct	14.5		17.0	9.0		6.46	5.37		6.84
Type of filter	f		b	b		g	g		g
Coal seam	b		c	b		j	j		j

Mesh Size	Test No. 25 Wt, Pct	Mesh Size	Test No. 26 Wt, Pct
+20	1.17	14 x 20	13.10
20 x 30	5.49	20 x 48	32.75
30 x 40	13.83	48 x 65	11.79
40 x 50	10.67	65 x 100	5.24
50 x 60	8.75	100 x 200	7.96
60 x 70	3.88	200 x 325	6.45
70 x 80	5.23	−325	22.71
80 x 100	18.60		
100 x 140	24.96		
140 x 200	4.37		
−200	2.83		
Average cake size, in.	0.0120		0.0162
Surface moisture of cake, pct	21.5		21.0
Type of filter	b		i
Coal seam	d		d

[a] Horizontal filter
[b] Outside drum filter
[c] Miller B and Upper Freeport (Mixed)
[d] Pennsylvania, Pittsburgh
[e] Great Britain, various seams
[f] Hopper dewaterer
[g] Laboratory pressure filter
[h] Ohio, Pittsburgh No. 8
[i] West Virginia, No. 2 Gas
[j] Illinois No. 5
[k] Inside drum and disk combination
[l] Genter filter

Fig. 1 reveals that coal has one size-moisture relationship and that mineral concentrates have other but parallel relationships. Since most of the data were gathered under operating conditions, the dotted lines enclosing 1—the coal points and 2—the mineral points represent the extremes in cake moisture content that would be obtained in plant operation.

These sets of relationships are not identical because of 1—specific gravity differences and 2—shape and surface characteristic differences. Coal particles, whether hard and blocky or platy and friable apparently have very similar shape and surface characteristics. Mineral concentrates fall into three groups, granular concentrates, flotation concentrates, and slime concentrates. The solid lines, Fig. 1, represent the average conditions that may be obtained in an operating plant. One such average condition is shown for coal, one for magnetic and oolitic granular iron concentrates, and one for sulphide and fluorspar flotation concentrates. Another such average condition could be anticipated for the slime iron concentrate (Test 21). It seems indicated that these average values should be used for the various types of materials when predicting operating results.

The wide variations in cake moisture obtained under operating conditions, when treating a given size-consist material, are the result of 1—fluctuations in plant tonnage, 2—fluctuations in feed solid content, 3—gradual wearing or blinding of filter cloths, and 4—the approximate method used to determine surface area.

Apparently there is a minimum moisture content obtainable for any given size-consist of cake. When applying the dewatering forces that can be brought to bear on the particles, using makes of filters currently available, the water film remaining on the particles has a minimum thickness for any particular material and therefore minimum cake moisture is a direct function of surface area. Failure to operate

Table II. Size-Consist and Miscellaneous Data for Various Mineral Concentrate Filter Cakes

Mesh Size	Test No. 1 Wt, Pct	Test No. 2 Wt, Pct	Test No. 3 Wt, Pct	Test No. 4 Wt, Pct	Test No. 5 Wt, Pct	Mesh Size	Test No. 6 Wt, Pct	Test No. 7 Wt, Pct	Test No. 8 Wt, Pct	Test No. 9 Wt, Pct	Test No. 10 Wt, Pct
+10	0.23	0.22	1.1	0.5	0.37	+20	1.4	2.8	2.3	1.4	1.17
10 x 20	0.84	0.75	1.9	1.8	1.87	20 x 100	47.5	52.3	41.8	50.3	49.23
20 x 35	5.03	4.93	9.4	11.2	10.15	100 x 200	23.0	22.3	26.3	28.2	23.36
35 x 65	20.8	22.8	27.8	24.3	30.55	−200	28.1	22.6	29.6	20.1	26.24
65 x 100	17.3	17.4	16.1	16.1	13.86						
100 x 200	26.9	30.2	21.4	17.6	21.50						
−200	28.9	23.7	22.3	28.5	21.70						
Average cake size, in.	0.0089	0.0071	0.0093	0.0092	0.0096		0.0113	0.0127	0.0108	0.0119	0.0118
Total moisture of cake, pct	7.0	6.0	6.3	10.9	6.0		7.3	9.2	7.1	6.7	7.2
Type of filter	a	a	a	a	a		a	a	a	a	a
Material filtered	b	b	b	b	b		b	b	b	b	b

Mesh Size	Test No. 11 Wt, Pct	Mesh Size	Test No. 12 Wt, Pct	Mesh Size	Test No. 13 Wt, Pct	Test No. 14 Wt, Pct	Mesh Size	Test No. 15 Wt, Pct	Test No. 16 Wt, Pct	Mesh Size	Test No. 17 Wt, Pct
20 x 28	2.85	+100	7.78	+48	0.6						
28 x 35	3.86	100 x 150	9.27	48 x 65	2.3	0.8	+150	0.6	2.0	+100	6.5
35 x 48	8.50	150 x 200	6.96	65 x 100	7.9	2.4	150 x 200	3.8	7.0	100 x 150	12.5
48 x 65	12.58	200 x 325	12.19	100 x 150	14.0	5.1	200 x 325	15.8	24.4	150 x 200	15.2
65 x 100	13.48	−325	63.80	150 x 200	16.6	10.7	−325	79.8	66.6	−200	65.8
100 x 150	11.63			200 x 270	13.7	14.7					
150 x 200	13.58			−270	44.9	66.3					
−200	31.52										
Average cake size, in.	0.0069		0.0036		0.0034	0.0026		0.0018	0.0020		0.0031
Total moisture of cake, pct	8.0		13.0		11.0	8.0		8.0	11.0		11.0
Type of filter	a		c		a	c		a	d		c
Material filtered	b		e		f	g		h	f		i

Mesh Size	Test No. 18 Wt, Pct	Mesh Size	Test No. 19 Wt, Pct	Mesh Size	Test No. 20 Wt, Pct	Test No. 21 Wt, Pct
+ 100	5.0	+150	4.8	+14	0.8	
100 x 200	14.0	150 x 200	15.5	14 x 20	2.5	
−200	81.0	200 x 325	19.6	20 x 35	15.7	
		−325	60.1	35 x 65	40.3	0.1
				65 x 100	25.1	1.5
				100 x 200	12.9	10.1
				−200	2.7	
				200 x 325		14.3
				−325		74.0
Average cake size, in.	0.0028		0.0022		0.0126	0.0021
Total moisture of cake, pct	10.0		12.0		7.0	22.0
Type of filter	c		c		c	d
Material filtered	i		i		j	k

[a] Inside drum filter
[b] Magnetic iron concentrates
[c] Outside drum filter
[d] Disk filter
[e] Copper concentrate
[f] Zinc concentrate
[g] Lead concentrate
[h] Copper-lead concentrate
[i] Fluorspar concentrate
[j] Oolitic iron concentrates
[k] Slime iron concentrate

a filter properly will provide a cake having a higher than theoretical moisture.

Conclusions

By means of the relationships presented, it is possible to predetermine average cake moisture and the variations in cake moisture to be anticipated when dewatering coal, granular mineral concentrates, flotation mineral concentrates, and slime mineral concentrates by vacuum filters under normal operating conditions. Apparently all of the makes of filters currently available are equally effective from a moisture reduction standpoint.

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Using Electric Furnaces and Heaters To Determine the Free-Swelling Index of Coal

by E. Swartzman and G. C. Behnke

THE free-swelling index, a numerical value for the free-swelling properties of coal, is being used to an increasing extent in specifying coal for burning in various types of equipment. The empirical standard ASTM method for determining this index uses, as a source of heat, a gas burner which requires frequent calibration because gas pressures are not constant, relatively small changes in gas pressure resulting in rather wide variations in the temperature attained in a crucible and thus in the resultant size of the coke *button*. Furthermore, the quartz crucibles specified for the test are not standard equipment, and relatively small variations in dimension and wall thickness from those specified often result in rather wide variations in the resultant size of the button.

A method of analysis to be satisfactory not only for a scientific laboratory but also for use in industrial control laboratories under varying conditions should employ equipment which is rugged, easily calibrated, and readily replaceable by standard materials. Gas is not universally available as is electricity, and it is generally easier to calibrate and control a simple electric furnace or heater than a gas burner, the voltage not usually fluctuating to the degree that gas pressure does. Quartz crucibles are fragile, and the size specified in the test is not normally used for any other purpose in the laboratory. Although more expensive, the 15-cc platinum crucible, available in all laboratories where volatile matter in coal is determined by the standard ASTM method, is sturdy and standard and easily replaced.

Because of these considerations, a modification of the standard method has been developed which employs a standard laboratory 350-w cone heater and standard 15-cc platinum crucibles. The results of numerous tests conducted with such apparatus show conclusively that the free-swelling index values as judged by the buttons produced with this equipment are exactly the same as those obtained by the standard gas burner method.

Thus it is suggested that this electric cone heater method employing standard 15-cc platinum crucibles be considered as an alternative to the ASTM method, Designation: D720-46.

The free-swelling index of coal is determined by means of the ASTM method, D720-46. This method, which is an adaptation of the crucible swelling test for coal of the British Standards Institution, consists of heating 1 g of coal in a special covered quartz crucible in a regulated gas flame for a period of not less than 2.5 min in which time the temperature of the inner surface of the bottom of the crucible reaches a temperature of 820±5°C. The residual coke button is then compared in size and shape with a series of standard profiles shown in Fig. 1 and designated by number from 1 to 9 in increasing order of size.

As the method is empirical, it requires rigid standardization of the apparatus and repeated calibration of the gas burner. The dimensions of the low form quartz crucible recommended must be rigidly adhered to as small variations in diameter or wall thickness result in variations in the rate of heat transmission and thus in the resultant size and shape of the coke button. The gas burner must be calibrated almost every time a new set of determina-

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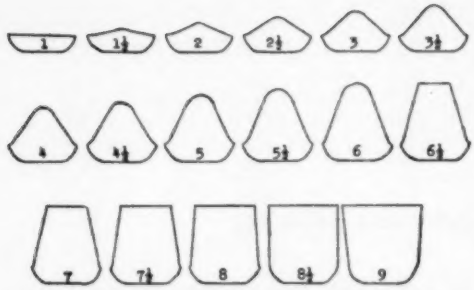

Fig. 1—Standard profile and corresponding swelling index numbers. Reproduced approximately one half full size.

tions are made because gas pressures are not constant. In addition, the method is not universally adaptable because gas is not available at all laboratories, especially at mines where it may be desirable to check every car of coal prior to shipment. Furthermore, it requires the use of equipment which is not standard and not always readily available especially insofar as the crucibles are concerned.

A method which is to be satisfactory for use at a mine tipple, coke plant, railway yard, power plant, or other industrial plant should be fairly rugged, easy to calibrate, simple to operate, and make use of standard equipment readily obtainable.

With this in view, a method has been developed whereby a simple electric laboratory cone heater supplies the source of heat and the standard covered 15-cc platinum crucible, used in determining the volatile matter of coal by the standard ASTM method is employed for preparing the coke buttons, which are then compared to the standard profiles. The coal is heated at a temperature of 650°C, inside the crucible bottom, for 4 min.

Equipment and Coals Tested

Two types of electric heaters were used in this investigation.

The first experiments were conducted with a 485-w multiple unit electric vertical tube furnace with an inside depth of 4½ in. and inside diam of 2⅜ in. Temperature control was attained by controlling the voltage with a Variac.

A 350-w electric cone heater, recommended as a substitute for the Bunsen burner, was used in the second group of experiments. This heating unit consists of an open helical spiral element of chromel wire lightly secured by alundum cement to the sides of a conical depression in a refractory heat-insulating block. The conical arrangement of the glowing wire focuses the radiant heat to produce the so-called spot-heating effect of a Bunsen burner.

This heater has an overall height of 6¼ in., and the top, 5¾ in. diam, is fitted with three concentric rings with openings of 1¼ in., 2 in., and 3⅛ in. diam. Depending upon the size of the crucible, rings of varying diameter had to be made up, so that the crucible fits well into the furnace with only about ⅛ in. protruding above the ring. To prevent undue loss of heat due to convection, a transite chimney 1¾ in. high and about 4 in. in diam was placed on the top. Temperature control was attained by means of a Variac. Figs. 2 and 3 show the details of the cone heater.

The seven different types of crucibles employed in this study were as follows: Type A—Quartz, low form, rim diam 36 mm, height 26 mm, capacity 19 ml. This crucible was used in the standard ASTM free-swelling test. Type B—Quartz, high form, rim diam 32 mm, height 38 mm, capacity 21+ ml. Type C—Platinum, 25 cc, rim diam 35 mm, height 35 mm, capacity 25 ml. Type D—Porcelain, wide form (Coors 0), rim diam 41 mm, height 25 mm, capacity 18 ml. Type E—Porcelain, high form (Coors 0), rim diam 35 mm, height 27 mm, capacity 15 ml. Type F—Nickel, high form, rim diam 36 mm, height 34 mm, capacity 28 ml. Type G—Platinum, 15 cc, rim diam 32 mm, height 32 mm, capacity 18.5 ml. This crucible conforms to the specifications of the standard ASTM volatile matter test described under ASTM Designation: D271-48, which specifies platinum crucibles of not less than 10 or more than 20-ml capacity, of not less than 25 or more than 35 mm in diam, and not less than 30 nor more than 35 mm in height.

Table I. Description of Canadian Coals

Sample No.	Origin	Seam	Size	Rank*
B13612	Sydney Area, Nova Scotia	Harbour	Channel	H.V.A. Bit.
B13666	Sydney Area, Nova Scotia	Harbour	Channel	H.V.A. Bit.
B13735	Sydney Area, Nova Scotia	Phalen	Slack	H.V.A. Bit.
32625	Sydney Area, Nova Scotia	Mixed	Slack	H.V.A. Bit.
32649	Sydney Area, Nova Scotia	Mixed	Slack	H.V.A. Bit.
B13702	Sydney Mines Area, Nova Scotia		Lump	H.V.A. Bit.
B13704	Sydney Mines Area, Nova Scotia		Lump	H.V.A. Bit.
32736	Sydney Mines Area, Nova Scotia	Harbour	Stoker	H.V.A. Bit.
32920	Sydney Mines Area, Nova Scotia	Harbour	Channel	H.V.A. Bit.
32940	Sydney Mines Area, Nova Scotia	Harbour	Channel	H.V.A. Bit.
32958	Sydney Mines Area, Nova Scotia	Harbour	Channel	H.V.A. Bit.
32976	Sydney Mines Area, Nova Scotia	Harbour	Channel	H.V.A. Bit.
32993	Sydney Mines Area, Nova Scotia	Harbour, Rider	Channel	H.V.A. Bit.
B13706	Joggins Area, Nova Scotia	Forty Brine	Lump	H.V.A. Bit.
B13710	Joggins Area, Nova Scotia	Forty Brine	Pea	H.V.A. Bit.
32690	Joggins Area, Nova Scotia	Forty Brine	Slack	H.V.A. Bit.
32681	Pictou County, Nova Scotia		Lump	H.V.A. Bit.
32450	Crowsnest Area, Alberta	No. 2	Lump	M.V. Bit.
32542	Crowsnest Area, Alberta	No. 2	Stoker	M.V. Bit.
32683	Crowsnest Area, Alberta	No. 1	Lump	M.V. Bit.
32667	Crowsnest Area, Alberta	No. 2	Middlings	M.V. Bit.
32692	Crowsnest Area, Alberta	No. 2	Fines	M.V. Bit.
32707	Crowsnest Area, Alberta	No. 2	Fines	M.V. Bit.
32803	Crowsnest Area, Alberta	No. 1	Briquettes	M.V. Bit.
32735	Crowsnest Area, Alberta	No. 2	Slurry	M.V. Bit.
32737	Crowsnest Area, Alberta	No. 2	Mine Run	M.V. Bit.
32770	Crowsnest Area, Alberta	No. 2	Mine Run	M.V. Bit.
32850	Crowsnest Area, Alberta	No. 2	Mine Run	M.V. Bit.
32817	Crowsnest Area, Alberta	No. 2	Mine Run	M.V. Bit.
33011	Crowsnest Area, Alberta	Nos. 2, 4	Lump	M.V. Bit.
33036	Crowsnest Area, Alberta	Nos. 2, 4	Lump	M.V. Bit.
33056	Crowsnest Area, Alberta	Nos. 2, 4	Slack	M.V. Bit.
33101	Crowsnest Area, Alberta	Nos. 2, 4	Stoker	M.V. Bit.
33123	Crowsnest Area, Alberta	Nos. 2, 4	Fines	M.V. Bit.
33145	Crowsnest Area, Alberta	Nos. 2, 4	Slurry	M.V. Bit.
32358	Crowsnest Area, B. C.	Nos. 4, 9, 10	Slack	M.V. Bit.
32650	Mountain Park Area, Alberta		Briquettes	M.V. Bit.

* H.V.A. Bit. = high volatile A bituminous.
M.V. Bit. = medium volatile bituminous.

Table II. Description of United States Coals

Sample No.	Origin	Seam	Size	Rank*
A501	Hopkins Co., Ky.	Nos. 9, 11	1¼" Stoker	H.V.B. Bit.
A491	Armstrong Co., Pa.	L. Kittaning	⅛ x 1¼ in.	H.V.A. Bit.
A513	Harrison Co., W. Va.	Pittsburgh	¾ x 2 in.	H.V.A. Bit.
A468	Ohio Co., W. Va.	Pittsburgh No. 8	⅝ x 1¼ in. Pea	H.V.A. Bit.
A512	Mingo Co., W. Va.	Thacker	Stoker	H.V.A. Bit.
A473	Pennsylvania		1⅛ x 2 in.	H.V.A. Bit.
A471	Armstrong Co., Pa.	L. Kittaning	⅝ x 1¼ in.	H.V.A. Bit.
A506	Logan Co., W. Va.	Island Creek	¼ x 1¼ in.	H.V.A. Bit.
A475	Fairmont Dist., Va.		Nut Slack	H.V.A. Bit.
A470	Floyd Co., Dist. No. 8, Ky.	Elkhorn No. 3	⅛ x1 in.	H.V.A. Bit.
A493	Letcher Co., Ky.	Elkhorn No. 3	⅛ x ⅜ in.	H.V.A. Bit.
A505	Fayette Co., W. Va.	Sewell	0 x 2 in.	H.V.A. Bit.
A525	Harlan Co., Ky.	Darby No. 5	Stoker	H.V.A. Bit.
A482	Armstrong Co., Pa.	Upper Freeport	⅛ x ¾ in.	H.V.A. Bit.
32684	Armstrong Co., Pa.	Upper Freeport	Slack	H.V.A. Bit.
32886	Armstrong Co., Pa.	Upper Freeport	Slack	H.V.A. Bit.
32889	Tennessee	Upper Banner		H.V.A. Bit.
32890		Creek		H.V.A. Bit.
32891		Pond Creek		H.V.A. Bit.
32892	Buchanan Co., Va.	Clintwood		H.V.A. Bit.
32893	West Virginia	Pond Creek		H.V.A. Bit.
32894		Pittsburgh		H.V.A. Bit.
33094	Kentucky	Harlan	Stoker	H.V.A. Bit.
32885				H.V.A. Bit.
32624				H.V.A. Bit.
A495	Buchanan Co., Va.	Cary	⅛ x 1¼ in.	M.V. Bit.
A484	Cambria Co., Pa., Dist. No. 1	Miller or B	⅛ x ¾ in.	L.V. Bit.
A519	McDowell Co., W. Va.	Pocahontas No. 4	Stoker	L.V. Bit.
A498	McDowell Co., W. Va.	Pocahontas No. 4	⅛ x ¾ in.	L.V. Bit.
A489	McDowell Co., W. Va.	Pocahontas No. 4	Stoker	L.V. Bit.
32888		Miller or B	Slack	L.V. Bit.
32887	West Virginia	Pocahontas No. 3	Slack	L.V. Bit.
33093		Pocahontas No. 3	Briquettes	L.V. Bit.

* H.V.A. Bit., high volatile A bituminous.
M.V. Bit., medium volatile bituminous.
L.V. Bit., low volatile bituminous.
H.V.B. Bit., high volatile bituminous.

Table III. Analysis of Canadian Coals

Sample No.	Total Moisture, Pct	Analysis, Dry Basis			Rank* ASTM
		Ash, Pct	Volatile Matter, Pct	Fixed Carbon, Pct	
B13612	2.1	4.3	38.3	57.4	H.V.A. Bit.
B13666	2.3	5.7	37.9	56.4	H.V.A. Bit.
B13735	1.2	5.7	35.7	58.6	H.V.A. Bit.
32625	10.8	11.8	33.0	55.2	H.V.A. Bit.
32649	2.8	10.0	33.8	56.2	H.V.A. Bit.
B13702	3.6	11.1	38.2	50.7	H.V.A. Bit.
B13704	3.6	12.3	37.7	50.0	H.V.A. Bit.
32736	8.0	17.4	34.8	47.8	H.V.A. Bit.
32930	1.9	5.6	36.9	57.5	H.V.A. Bit.
32940	2.4	5.5	36.8	57.7	H.V.A. Bit.
32958	2.3	4.3	38.0	57.7	H.V.A. Bit.
32976	2.1	4.9	37.4	57.7	H.V.A. Bit.
32993	1.7	28.4	31.5	42.1	H.V.A. Bit.
B13706	2.6	18.6	36.9	44.5	H.V.A. Bit.
B13710	2.0	31.2	30.9	37.9	H.V.A. Bit.
32690	3.5	33.9	30.0	36.1	H.V.A. Bit.
32681	2.4	13.1	29.1	57.8	H.V.A. Bit.
32450	1.2	20.5	27.8	51.7	M.V. Bit.
32542	4.3	16.0	25.5	58.5	M.V. Bit.
32683	2.8	9.0	25.5	65.5	M.V. Bit.
32667	2.2	24.0	23.9	52.1	M.V. Bit.
32692	3.1	21.5	24.1	54.4	M.V. Bit.
32707	1.4	19.2	24.3	56.5	M.V. Bit.
32803	0.5	19.1	24.2	56.7	M.V. Bit.
32735	15.2	16.9	24.2	58.9	M.V. Bit.
32737	2.4	21.4	24.8	53.8	M.V. Bit.
32770	1.2	18.8	27.5	53.7	M.V. Bit.
32850	1.3	20.5	24.6	54.9	M.V. Bit.
32817	2.2	21.9	24.8	53.3	M.V. Bit.
33011	0.8	15.8	25.1	59.1	M.V. Bit.
33036	1.4	16.0	25.6	58.4	M.V. Bit.
33086	2.6	18.0	24.7	57.3	M.V. Bit.
33101	1.1	13.3	26.0	60.7	M.V. Bit.
33123	2.3	13.3	25.2	61.5	M.V. Bit.
33145	11.3	15.5	24.1	60.4	M.V. Bit.
32358	0.8	12.6	25.4	62.0	M.V. Bit.
32650	0.7	17.2	24.7	58.1	M.V. Bit.

* H.V.A. Bit., heavy volatile A bituminous.
M.V. Bit., medium volatile bituminous.

These crucibles are shown in Fig. 4. The platinum and nickel crucibles have tightly fitting insert lids, whereas the quartz and porcelain crucibles have cover lids which did not fit as tightly.

For this experimental work coals with a range in free-swelling properties from 1 to 9 were used. With a view to testing as wide a range in classes of coals as possible, coals from different fields in the United States as well as in Canada were used. The coals varied in rank from high volatile B bituminous to low volatile bituminous and were both of Carboniferous and Tertiary age.

Descriptions of the Canadian coals tested, showing origin, seam, size and rank, are given in Table I, and Table II presents similar data for the United States coals. Tables III and IV give the proximate analyses on the dry basis for the Canadian and United States coals.

Details of Tests

Vertical Tube Furnace: As a vertical tube furnace, often referred to as the Fieldner furnace, is used for standard volatile matter determinations at 950°C, and a low temperature tube furnace is used for determining the swelling index of coals by the Canadian Fuel Research Laboratories method,[1] a similar type of furnace first was employed in experiments to determine whether an electric furnace or heater could be used to replace the gas burner specified in the ASTM standard test for determining the free-swelling index of coal.

[1] E. Swartzman, E. J. Burrough and R. A. Strong: Laboratory Test on Coal for Predicting The Physical Properties of the Resultant By-Product Cokes. Canadian Dept. of Mines Pub. No. 737-1, 1933.

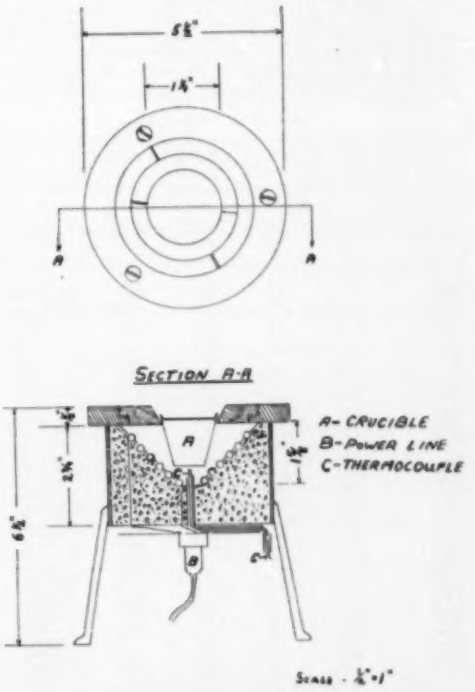

Fig. 2—Diagram of cone heater.

Fig. 3—Cone heater.

Two types of crucibles were used in these tests, type A, the quartz crucible recommended for the standard test, and type D, a porcelain wide form crucible somewhat similar in dimensions and capacity to the standard quartz crucible. Tests were conducted at seven different temperatures in 50°C steps from 450°C to 750°C. The temperature was that of the furnace and was taken by means of a noble metal thermocouple, the end of which was situated about ⅛ in. from the bottom of the crucible.

The free-swelling index results on 19 coals varying in index from 3 to 8 by the standard method are shown in Tables V and VI, Table V giving the results at different temperatures using the standard quartz crucible, and Table VI the results using the wide form porcelain crucible.

Tests with Cone Heater: In view of the unsatisfactory results obtained with the vertical tube furnace and because the electric cone heater is considered to be a substitute for the gas burner, this latter type was used in all subsequent experimental work.

Table IV. Analysis of United States Coal

Sample No.	Analysis, Dry Basis: Total Moisture, Pct	Ash, Pct	Volatile Matter, Pct	Fixed Carbon, Pct	Rank[a] ASTM
A501	9.1	7.2	42.0	50.8	H.V. Bit.
A491	3.6	9.1	38.6	52.4	H.V.A. Bit.
A513	2.2	9.1	36.5	51.6	H.V.A. Bit.
A468	3.4	11.1	37.7	51.2	H.V.A. Bit.
A512	2.5	5.9	37.5	56.6	H.V.A. Bit.
A473	1.7	9.4	36.7	53.9	H.V.A. Bit.
A471	2.6	9.3	36.5	54.3	H.V.A. Bit.
A508	4.4	7.4	36.6	56.0	H.V.A. Bit.
A475	4.5	9.5	35.6	54.9	H.V.A. Bit.
A470	2.5	6.6	35.3	57.9	H.V.A. Bit.
A493	5.7	5.2	34.7	60.1	H.V.A. Bit.
A505	0.0	9.8	34.3	55.8	H.V.A. Bit.
A525		3.9	34.2	61.9	H.V.A. Bit.
A482	3.4	10.9	32.1	57.0	H.V.A. Bit.
32884	1.3	11.3	33.2	55.5	H.V.A. Bit.
32886	3.7	11.5	34.9	53.6	H.V.A. Bit.
32889	1.1	8.4	32.2	59.4	H.V.A. Bit.
32890	2.0	7.9	36.1	56.0	H.V.A. Bit.
32891	2.3	6.3	38.7	55.0	H.V.A. Bit.
32892	1.8	7.2	33.3	59.5	H.V.A. Bit.
32893	2.1	6.8	35.9	57.3	H.V.A. Bit.
32894	1.4	8.7	34.0	57.3	H.V.A. Bit.
33094	4.7	4.4	39.5	56.1	H.V.A. Bit.
32885	16.8	8.7	37.0	54.3	H.V.A. Bit.
32624	7.0	9.1	34.3	56.6	H.V.A. Bit.
A495	3.1	10.1	21.3	68.6	M.V. Bit.
A484	1.9	8.8	17.3	73.9	L.V. Bit.
A519	1.2	8.3	15.4	76.3	L.V. Bit.
A498	2.4	6.9	15.2	77.9	L.V. Bit.
A489	2.6	6.3	15.1	78.6	L.V. Bit.
32888	0.5	8.5	18.1	73.4	L.V. Bit.
32887	0.7	9.1	17.8	73.1	L.V. Bit.
33095	0.3	7.2	24.1	68.7	L.V. Bit.

[a] H.V. Bit., heavy volatile bituminous.
H.V.A. Bit., heavy volatile A bituminous.

Fig. 4—Crucibles.

A—Quartz, low form, standard free-swelling test
B—Quartz, high form
C—Platinum, 25 cc
D—Porcelain, wide form
E—Porcelain, high form
F—Nickel, high high form
G—Platinum, 15cc, standard volatile matter test

The first series of tests with this furnace or heater was conducted at two temperatures, 600°C and 650°C. The temperature is that taken inside at the bottom of the crucible by means of a noble metal thermocouple. Six different types of crucibles, A, B, C, D, E and F, were employed, and two different heating times were used, 4 min and 15 min.

The results of these tests on seven different coals

Table V. Tests in Vertical Tube Furnace, Free-Swelling Index at Varying Temperatures Using the Quartz Crucible Type A,[a] See Fig. 5

Furnace Temp., °C / Sample No.	450 S.I.[b]	500 S.I.[a]	550 S.I.[a]	600 S.I.[a]	650 S.I.[a]	700 S.I.[a]	750 S.I.[a]	Standard Test S.I.[a]
A501	2	2	3	3	3	2.5	3	4+
A491	3	3.5	5.5	4.5	4	3.5	3	8
A513	3	4	5	4.5	5	4	3.5	7.5
A468	2	3.5	4.5	4.5	3.5	2.5	2.5	6
A512	3.5	3	4	4	3.5	2.5	2.5	5+
A473		9	8	8	4	3.5	3	8
A471	4	4	6.5	4.5	4	4.5	4	7.5
A508	1.5	2	3.5	5	4.5	3.5	3	6.5
A475	1.5	2.5	5	6	4.5	4	3	8
A470	0	2	3	3	2.5	2.5	2	3
A493	1	1.5	1.5	2.5	2	2	2	3
A505	1	1	1	1.5	2	1.5	1.5	3
A525	2	2	2.5	2.5	2	2	1.5	2.5
A482	9	9	9	5	4	4		6.5
A495	0	0	4	5.5	4	3	3.5	4.5
A484	0	1	1	1.5	3	3	3	4.5
A519	0	2	2	2.5	3.5	2.5	3	4.5
A498	0	0	1	1	2	2	3	4.5
A489	0	0	0	3.5	4	4.5	4	5.5

[a] Same crucible as used in standard test.
[b] Swelling index as determined by comparison of buttons to standard profiles.

Table VI. Tests in Vertical Tube Furnace, Free-Swelling Index at Varying Temperatures Using Porcelain, Wide Form, Crucible Type D, See Fig. 6

Furnace Temp., °C / Sample No.	450 S.I.[a]	500 S.I.[a]	550 S.I.[a]	600 S.I.[a]	650 S.I.[a]	700 S.I.[a]	750 S.I.[a]	Standard Test S.I.[a]
A501	1	1	1.5	2	2	2	2	4+
A491	2	3.5	5	6.5	6	5	4	8
A513	1.5	3	4.5	5.5	5	4.5	4	7.5
A468	1.5	2.5	3.5	4.5	4	3.5	3	6
A512	1	1.5	2	4	3.5	3.5	2	5+
A473	3	4	5.5	8.5	7	4.5	5	8
A471	1	1.5	3.5	5	5	5	4	7.5
A508	1	2	3	4	4.5	4	2.5	6.5
A475	1	2.5	3.5	5	6	5.5	4	8
A470	0	1	1	1.5	2	1.5	2	3
A493	0	1	1.5	2	2	2	2	3
A505	1	1	1.5	1.5	2	2	2	3
A525	1	1	1	1.5	2	1.5	1.5	2.5
A482	2.5	3	5	9	8.5	7.5	4	8.5
A495	0	2	2	3	4	6	5	4.5
A484	0	1	0	1	1.5	2	3	4.5
A519	0	0	1	1	2	3	3	4.5
A498	0	0	0	1	1.5	2	3	4.5
A489	0	0	0	1.5	3	4	4	5.5

[a] Swelling index as determined by comparison of buttons to standard profiles.

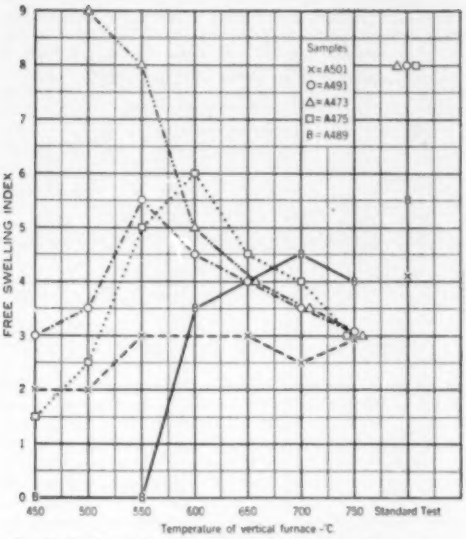

Fig. 5—Swelling indices at various temperatures using quartz crucible A, see Table V.

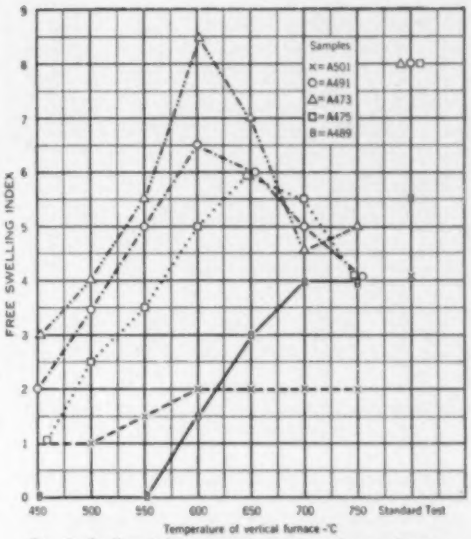

Fig. 6—Swelling indices at various temperatures using porcelain crucible D, see Table VI.

varying in free-swelling index from 3 to 8 are shown in Table VII.

The second series of tests with the cone heater was conducted at 600°C, 650°C, 700°C, and 820°C, using only the type A quartz crucible which is the type used in the standard test. The results of these tests on 17 coals are shown in Table VIII.

The third series of tests was conducted at two temperatures, 600°C and 650°C using the type G, 15-cc platinum crucible, which is the type recommended for use in the standard volatile matter test. The heating time in these tests was 4 min. The results on 24 coals, varying in free-swelling index from 2.5 to 8.5, are presented in Table IX.

The results of the above tests established the type of equipment and method to be employed in conducting a test using electrical heaters to give results comparable to those obtained with the standard gas burner method. To check how closely the results determined by the electric method compare with the results as determined by the standard method, a comparative series of determinations was conducted using the 350-w cone heater at 650°C and type G, 15-cc platinum crucibles with a 4-min heating period. The results obtained on 30 Canadian coals are shown in Table X, and similar results on 30 United States coals are presented in Table XI.

Discussion of Results

Vertical Tube Furnace Tests: The first series of tests using the electric vertical tube furnace was conducted to determine at what temperature, if any, the determination might be conducted using the standard quartz crucible, type A, to obtain buttons

Table VII. Tests with 350-W Cone Heater
Free-Swelling Index in Various Types of Crucibles at 600°C and 650°C With Varying Duration of Heats, See Figs. 7 and 8

Sample No.	Temp. in Crucible, 600°C						Temp. in Crucible, 650°C						Standard Test
	Type of Crucible*						Type of Crucible*						
	A	B	C	D	E	F	A	B	C	D	E	F	
A501													
4 min	1.5	2.5	2.5	2	2.5	1	2	3	2.5	2	3	2	4+
15 min	1.5	3	1.5	2	2.5	1	1.5	2.5	2.5	2.5	3	1.5	
A488													
4 min	3.5	6.5	5	5	5	3.5	4	6.5	3.5	4	5.5	4.5	6
15 min	3.5	6.5	5	5	4.5	3.5	4	6.5	7	5	5.5	2.5	
A512													
4 min	3	4	3	3.5	4	2	3	4.5	3	3.5	3	2.5	5+
15 min	2.5	3.5	2	3	4	1.5	2.5	5	3	3.5	4	2	
A473													
4 min	5.5	7	6	7	6	4.5	5.5	6	6	7.5	8.5	6	6
15 min	5	7	6	5.5	6	5.5	5.5	6	6	8.0	8	7.5	
A508													
4 min	3.5	5.5	4	4	5	2.5	4	6	4.5	4.5	5	2	6.5
15 min	3	5	3	4	4.5	2	3.5	6	6.5	4	5	2.5	
A470													
4 min	1.5	2.5	2	2	2	1	1.5	3	2	2	2	1	3
15 min	1.5	2	2	2	1.5	1	2	3	3	2.5	2	1	
A482													
4 min	4.5	7	6.5	7	7	7.5	6	8	8.5	7.5	7.5	8	8.5
15 min	5	6.5	9	5.5	7.5	5	5	9	8.5	7.5	7.5	9	

* Types of Crucibles: A—quartz, low; B—quartz, high; C—platinum, 25cc; D—porcelain, wide; E—porcelain, high; F—nickel, 28cc.

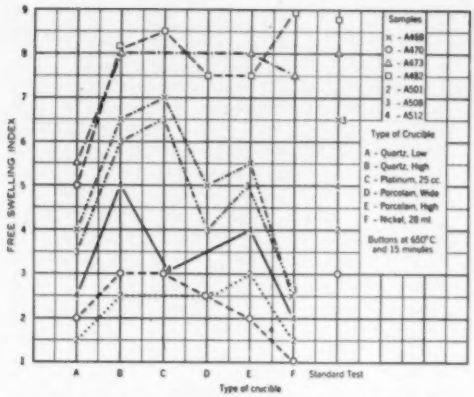

Fig. 7—Swelling index in various types of crucibles at 650°C in cone heater, see Table VII.

giving the same free-swelling index as when conducted by the standard gas burner method. The results shown in Table V are presented in graphic form in Fig. 5.

No two coals appeared to react the same. Some showed their highest swelling at the lower temperatures and some at the highest temperatures employed. Only in two cases out of 19 were values obtained which checked the free-swelling indices obtained by the standard method. The results are fairly conclusive in indicating that this combination of equipment was unsatisfactory for the purpose.

The results of the second series of tests using the same furnace and the type D, wide form, porcelain crucible are shown in Table VI, and presented in graphic form in Fig. 6. Again only two coals out of the 19 tested showed free-swelling values comparable to those obtained by the standard test. The results of this series also conclusively indicate that the above combination of equipment was unsatisfactory as a substitute for the gas burner method.

Cone Heater Tests: To determine whether and under what conditions the electric cone heater, considered to be a substitute for the Bunsen burner, could be employed to replace the standard gas burner method three series of tests were conducted.

Table VIII. Tests with 350-W Cone Heater Free-Swelling Index in Quartz Crucible Type A at Varying Temperatures, See Figs. 9 and 10

Sample No.	600°C S.I.[b]	650°C S.I.[b]	700°C S.I.[b]	820°C S.I.[b]	Standard Test S.I.[b]
A501	1.5	2	2.5	4	4+
A491	—	—	7.5	8	8
A513	—	—	7	7.5	7.5
A468	3.5	4	5.5	6.5	6
A512	3	3	4	5.5	5+
A473	5	5.5	8	8	8
A471	—	—	5.5	7	7.5
A508	3.5	4	5.5	6	6.5
A475	—	—	5.5	7.5	8
A470	1.5	2	2	3	3
A493	—	—	2.5	3	3
A505	—	—	2	3	3
A525	—	—	2	3	2.5
A482	0.5	5.5	8	8.5	8.5
A495	—	—	4	4.5	4.5
A484	—	—	2.5	4	4.5
A519	—	—	3	4	4.5

[a] Final temperature to be attained in standard test.
[b] Swelling index as determined by comparison of buttons to standard profiles.

Table IX. Test with 350-W Cone Heater. Comparison of Free-Swelling Index Results at 600°C and 650°C (Conducted in Type G, 15-cc Platinum Crucibles with 4-Min Heating) to Those by Standard Test, See Figs. 11 and 12

Sample No.	Using 15-cc Platinum Crucible in Cone Heater — Free Swelling Index 600°C	650°C	Standard ASTM Test — Free Swelling Index
A501	3.0	3.5	4.0
A491	7.5	8.0	8.0
A513	7.0	7.5	7.5
A468	6.5	6.0	6.0
A512	5.0	4.5	5.0
A473	8.5	8.0	8.0
A471	7.0	7.5	7.5
A508	6.5	6.5	6.5
A475	7.5	7.5	8.0
A470	2.5	3.0	3.0
A493	2.5	2.5	3.0
A505	2.0	2.0	3.0
A525	2.0	2.0	2.5
A482	9.0	9.0	8.5
A495	7.5	7.5	8.0
A484	3.5	4.5	4.5
A519	4.0	4.5	4.5
B13612	7.5	7.0	7.5
B13666	6.5	6.5	7.0
B13735	7.5+	7.5+	8.5
B13702	5.0	5.5+	6.0
B13704	5.0	5.5+	6.0
B13706	4.0	5.0	5.5
B13710	1.5	2.0	2.5

The first series was conducted at 600°C and 650°C using six different types of crucibles, the standard quartz, type A; a quartz high form, type B; a 25-cc platinum, type C; a wide form porcelain, type D; a high form porcelain, type E; and a high form nickel crucible, type F. Two subseries of tests were run using different heating periods, one at 4 min and the other at 15 min. The results of all these tests on seven different coals are shown in Table VII, with the results obtained at 650°C and 15 min heating being presented graphically in Fig. 7. A photographic record of the buttons for three of the coals is shown in Fig. 8.

First, the data indicate that a temperature of

Table X. Comparison of Free-Swelling Index as Determined with 350-W Cone Heater at 650°C Using 15-cc Platinum Crucibles and 4-Min Heating Period to Results of Standard ASTM Test Canadian Coals

Sample No.	Free-Swelling Index — Standard Test Index	Standard Test Volume of Button, ml	Cone Heater Test Index	Cone Heater Test Volume of Button, ml
32625	7.0	4.7	7.0	4.9
32649	8.0	5.9	7.8	5.2
32736	3.4	2.1	3.1	2.7
32920	6.5	4.9	6.5	4.9
32940	6.1	4.5	5.8	4.4
32958	6.5	4.8	6.4	5.1
32976	6.0	4.7	6.1	4.7
32993	5.5	3.1	5.6	3.9
32690	1.0	1.3	1.0	1.8
32681	4.8	3.1	4.0	3.1
32450	3.5	2.1	3.5	2.5
32542	2.0	1.6	1.5	2.1
32683	5.9	4.6	5.8	5.2
32667	1.5	1.1	1.5	1.4
32692	1.5	0.8	1.5	1.5
32707	1.5	1.3	1.5	1.9
32803	1.0	1.3	1.0	1.5
32735	1.0	1.1	1.0	1.4
32737	2.0	1.8	1.5	1.9
32770	3.5	2.5	2.9	2.8
32850	2.5	1.8	2.5	2.3
32817	1.6	1.5	1.5	1.8
33011	3.5	2.4	3.0	2.2
33036	3.5	2.3	4.1	3.2
33056	4.0	2.5	4.0	3.3
33101	3.5	2.5	3.5	3.5
33123	4.0	3.1	3.9	3.7
33145	3.0	2.2	3.2	2.6
33358	8.0	6.4	8.0	7.2
32650	1.0	1.3	1.5	1.4

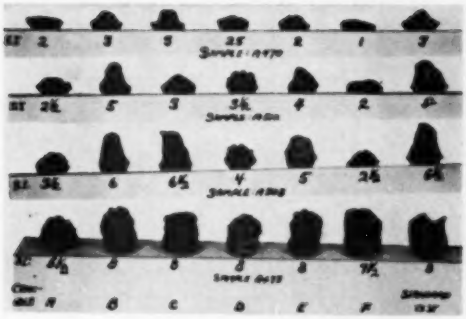

Fig. 8—Comparison of coke buttons prepared at 650°C in various types of crucibles using a cone heater, see Table VII.

650°C appears to give results approaching a little more closely those obtained by the standard method than does a temperature of 600°C. In addition, heating for a period longer than 4 min does not appear to make any appreciable difference in most cases. Of all the crucibles tested the type B high form quartz and the 25-cc platinum type C gave the most consistent results in comparison to the standard, with the platinum crucible showing slightly more consistency.

To determine whether the standard quartz crucible type A might be suitable at some different temperature than those used above, a second series of tests was run on 17 coals at temperatures of 600°C, 650°C, 700°C, and 820°C, the latter being the temperature specified in the standard gas burner method. The results of these tests are shown in Table VIII and are presented graphically in Fig. 9. A photographic record of the buttons from four of the coals tested is shown in Fig. 10. These results show conclusively that the standard quartz crucible when used in the cone heater at 820°C, the standard heating temperature, gives results close to those obtained by the standard gas burner method. Thus all other conditions remaining the same, the cone heater may be used to replace the gas burner.

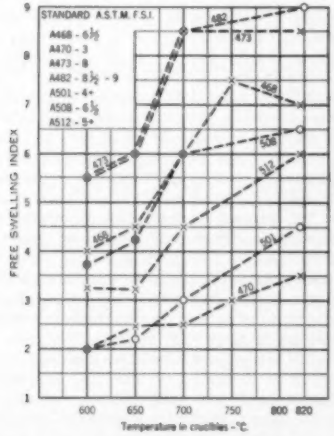

Fig. 9—Free-swelling index in quartz, type A crucible at varying temperatures, see Table VIII.

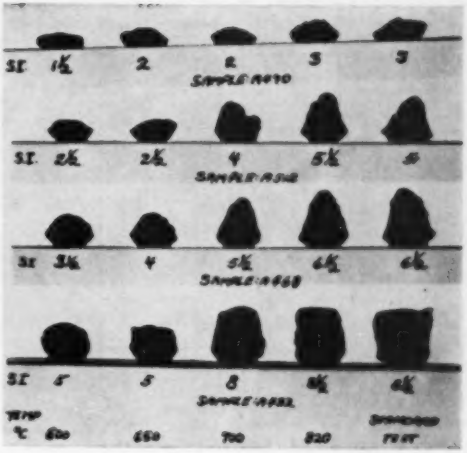

Fig. 10—Comparison of coke buttons prepared in crucible type A (quartz) at varying temperatures, see Table VIII.

However, as the quartz crucible is not usually available as standard equipment, a third series of tests was conducted to determine whether the 15-cc platinum crucible, type G, used in determining volatile matter by the standard ASTM method, would be suitable to replace the quartz crucible. Preliminary experimentation indicated that a temperature of 600°C to 650°C would be suitable for platinum crucibles in comparison to 820°C for quartz because of the comparatively high heat conductivity of platinum. A series of tests was conducted at these two temperatures with a 4-min heating period. The results obtained on 24 Canadian and United States coals of varying rank and with free-swelling indices

Table XI. Comparison of Free-Swelling Index as Determined with 350-W Cone Heater at 650°C Using 15-cc Platinum Crucibles and 4-Min Heating Period to Results of Standard ASTM Test, United States Coals

Sample No.	Free-Swelling Index			
	Standard Test		Cone Heater Test	
	Index	Volume of Button, ml	Index	Volume of Button, ml
A501	4.0		3.5	
A491	8.0		8.0	
A513	7.5		7.5	
A468	6.0		6.0	
A512	5.0		4.5	
A473	8.0		8.0	
A471	7.5		7.5	
A508	6.5		6.5	
A475	8.0		7.5	
A479	3.0		3.0	
A483	2.0		2.5	
A505	3.0		2.0	
A535	2.5		2.0	
A482	8.5		9.0	
32884	8.1	6.9	8.4	7.3
32886	8.0	7.2	7.5	7.2
32889	7.0	5.2	7.0	5.3
32890	5.4	4.1	5.1	3.7
32891	5.5	4.0	5.0	3.9
32892	7.5	6.5	7.5	5.8
32893	6.5	4.7	5.4	4.7
32894	7.6	5.7	7.5	6.1
33094	4.3	2.7	4.4	3.5
32885	5.0	4.2	5.5	4.8
A495	8.0		7.5	
A484	4.5		4.5	
A519	4.5		4.5	
32888	7.0	5.0	6.1	4.7
32887	7.5	6.9	7.6	6.4
33095	9.0	8.6	8.5	8.6

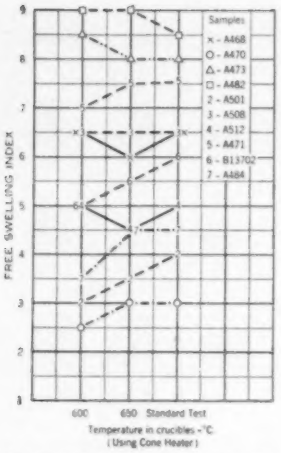

Fig. 11—Swelling indices at varying temperatures in 15-cc platinum crucibles in comparison to standard test results.

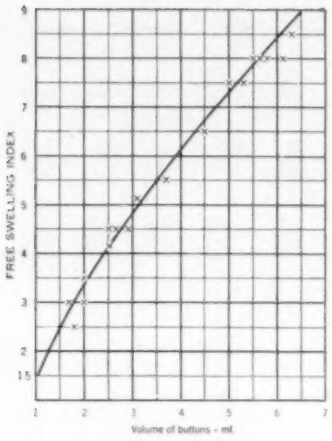

Fig. 13—Relationship of volume of buttons to free-swelling index, standard test.

varying from 2.5 to 8.5 are shown in Table IX, the results on some of the coals being shown graphically in Fig. 11. In addition, a photographic record of the buttons from four of the coals tested is shown in Fig. 12.

These results indicate conclusively that at a temperature of 650°C, inside the crucible, free-swelling index values are obtained which check very closely the results obtained by the standard gas burner method irrespective of the rank of the coal, its origin, or its swelling properties.

To determine whether consistently comparable results could be obtained over a period of time when the method (cone heater, 650°C, 15-cc platinum crucible, 4-min heating time) is used in the regular routine of the laboratory, the free-swelling indices of 30 Canadian and 30 United States coals were determined in parallel with the standard gas burner method. The results shown in Tables X and XI, indicate that the cone heater method gives free-swelling values comparable to those obtained by the gas burner method, irrespective of the free-swelling properties of the coals, their rank, origin, or geological age.

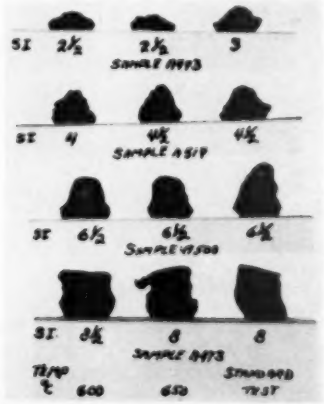

Fig. 12—Comparison of coke buttons at 600°C and 650°C prepared in 15-cc platinum crucible, type G, using a cone heater, see Table VII.

As the free-swelling indices of the coals are obtained by comparing the buttons to a series of standard profiles, a further check on the comparison between the size of the buttons as obtained by the cone heater and gas burner methods was desirable. Thus the volumes of the buttons were determined. This was done in the following manner. First the volume of the crucibles was measured with 150x200 mesh sand pouring the sand into the crucibles from a funnel with the outlet end placed exactly 3¾ in. above the rim of the crucible. The crucible full of sand was tapped six times, scraped level and then poured into a 10-cc graduated cylinder, tapped six times and the volume obtained. After running a test and before removing the button from the crucible, sand is poured into the crucible in the manner described above until the void is filled. The sand volume is measured as above. The volume of the button then is:

Volume of crucible — volume of void.

Table XII presents data on a series of coals showing the relationship of the free-swelling index to the volume of the buttons as obtained by using the standard ASTM gas burner method. Fig. 13 presents the relationship in a graphic manner, the volume of the buttons being plotted against the free-swelling indices. The almost straight line obtained indicates that the index is directly proportional to the volume of the buttons.

In Tables X and XI, in addition to the free-swelling indices, the average volumes of the buttons, four for each determination, are shown both as obtained by the standard test and by the modified cone heater test. It is of importance to note that the volume of the buttons as obtained by the two methods check very closely, as do the free-swelling indices. Thus it may be concluded that for all practical purposes the index as obtained by comparison to the standard profiles is sufficiently accurate to define the free-swelling properties of the coal.

Occurrence And Exploration Of Georgia's Kaolin Deposits

Fig. 1—Principal kaolin-producing area of Georgia, with index map showing relation of the area (black) to the Coastal Plain and the Piedmont Plateau.

by Thomas L. Kesler

IF all of the 14 million tons of kaolin produced in Georgia through 1949 had been mined from a single deposit 20 ft thick, it would represent a mined-out area of less than 1 sq mile. This measure of depletion is in such strong contrast with the large size of the area shown in Fig. 1, from which most of the output has come, that there has developed an optimistic outlook concerning future supplies of kaolin equal in grade to that already mined. Dozens of mines are widely but not evenly distributed within this area, which consists mostly of parts of Twiggs, Wilkinson, and Washington counties. There are scarcely half a dozen kaolin mines elsewhere in the state that have been appreciably productive, although the areas in which they occur may have good possibilities. Most of the efforts to find new deposits, therefore, will be confined to the area shown in Fig. 1, for it is here that the industry has established its facilities, and prospecting is encouraged by relatively numerous outcrops and opened deposits of kaolin.

The Ocmulgee and Oconee rivers drain the area. They and their main tributaries have flat, swampy floodplains covered with alluvium and for the most part thickly wooded. The divides between these streams are intricately dissected by the minor tributaries, which are spring-fed in steep-walled, cirque-like heads. Gullying and under-cutting are active along the streams but are partly controlled by unusually dense vegetation. The mean altitude is about 350 ft above sea level, and locally the relief ranges up to 200 ft.

The area is near the inner margin of the Coastal Plain, and is underlain by Cretaceous and Tertiary formations. Its general location is shown in black in Fig. 1. The division between the Coastal Plain and the Piedmont plateau is actually a very sinuous line, the fall line, marking the extent to which erosion has stripped the Coastal Plain sediments from the southeastward-sloping surface of the crystalline rocks of the Piedmont.

Cretaceous Host Formation

The kaolin deposits, which are described in the succeeding section, occur sporadically in lenslike bodies in a thick series of poorly sorted clayey sands constituting the lowermost of the Upper Cretaceous formations, the Tuscaloosa. The basis for this correlation has been reviewed by Cooke.[1] The same formation has been termed the Potomac group by Ladd[2] and the Middendorf formation by Smith[3] in reports on the kaolin deposits. In another report, Veatch[4] called the formation the Tuscaloosa but correlated it with the Lower Cretaceous.

The Tuscaloosa in this area consists of fine to very coarse sands, commonly cross-bedded, which contain widely different proportions of white, pink, and yellow kaolin and considerable white mica. A few of the coarser beds contain quartz grains up to ¾ in. in length, with bodies of pure white kaolin of equal size that appear to have been formed by the weathering of feldspar grains in place. In the kaolin-producing area, gravel and cobbles occur mainly at the base of the formation. Fig. 2 shows the relations of the Tuscaloosa and its kaolin deposits to the adjacent formations. Its base, on the eroded surface of the crystalline rocks, dips southeastward 50 to 60 ft to the mile, according to LaMoreaux.[5] The upper surface of the Tuscaloosa is also an unconformity,

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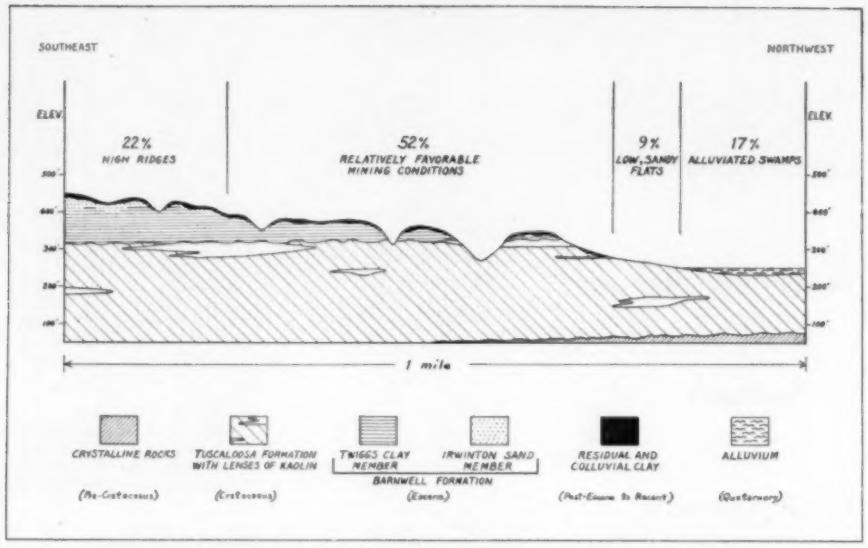

Fig. 2—Cross-section showing relations and typical occurrence of the Georgia kaolin deposits. Vertical scale is exaggerated.

and the maps of Warren and Thompson[6, 7, 8] indicate that this surface strikes about N. 45°E. and dips southeastward 11 to 15 ft to the mile. As the upper surface of the Tuscaloosa dips less steeply than the base, the formation thickens southeastward from zero along the fall line to about 600 ft[3] along the southeast edge of the area shown in Fig. 1.

Eocene Overburden Formation

The Barnwell formation, of Eocene age, rests on the Tuscaloosa, and its beds appear to have the same strike and dip as does the unconformity at its base. In the kaolin-producing area, the Tuscaloosa is exposed mostly in valley lands, where the Barnwell has been removed by erosion, as shown in Fig. 2. Owing to the intricate stream system, the contact between the formations is too complex to be shown on any map small enough to accompany this paper, and the reader is referred to the excellent maps of Warren and Thompson.[6, 7, 8]

The Barnwell consists of two members that intergrade vertically but not everywhere at the same stratigraphic level, and consequently there must also be considerable horizontal intergrading. The lower member, the Twiggs clay, consists mostly of fullers earth, in many places unevenly sandy and calcareous and containing random beds of fossiliferous limestone as much as 4 ft thick. These limestone beds, containing the fauna of the Ocala limestone, occur interbedded with the fullers earth from the base of the member upward as much as 65 ft. Hard, sandy, calcareous beds are most numerous in the lower 15 ft of the member. They yield readily to weathering along outcrops, where they have been altered to sand of different colors, which has been commonly noted in lithologic descriptions of the lower part of the Twiggs clay.

The "channel sands" above the Tuscaloosa, described by Warren and Thompson[6, 7, 8] and by LaMoreaux,[5] are probably in places these leached sandy beds at the base of the Twiggs clay, but in other places they probably include both the residual and colluvial clay, described below, and parts of the Tuscaloosa itself. No basis has been found, in the present work, for recognizing channel sands as a stratigraphic unit. All of the Twiggs clay except the purer limestone beds is olive green to greenish yellow if leached, and dark, bluish gray if relatively unweathered. The Twiggs clay member is about 80 ft thick over much of the area, but was found to be 115 ft thick in a hole drilled 5.2 miles northeast of McIntyre. The member has been studied in detail by Shearer,[9] as the fullers earth is of commercial grade in some places.

With the occurrence of thin beds of sand in its upper part, the Twiggs clay grades into the overlying member, the Irwinton sand. This member consists largely of white to yellow sand, but contains a few, thin, waxy, red to gray beds that may be much weathered fullers earth. The least weathered of the sand is loosely cemented with a white, noncalcareous material, evidently silica.

Younger Overburden Formations

A mantle of deep-red sandy clay as much as 10 ft thick overlies the two members of the Barnwell as well as parts of the Tuscaloosa, regardless of altitude, see Fig. 2. Locally, it contains transported fragments of limonitic hardpan, itself a product of weathering. In some of the mine openings the red, sandy clay can be seen forming directly from the weathering of sandy, calcareous fullers earth in the lower part of the Twiggs clay, and slumping has carried some of it down over adjacent parts of the Tuscaloosa. However, where the red, sandy clay covers the Irwinton sand high on the divides, the origin differs. In this position, the clay is undoubtedly the residuum of beds destroyed by weathering, pos-

sibly fullers earth beds that were in or that overlay the Irwinton sand. Although the red mantle is physically continuous from divides to valleys, it appears that its source is diverse. Development of the clay began after Eocene time and is still going on.

Probably the youngest of the formations associated with the kaolin deposits is the alluvium that has been deposited on the wider flood-plains, converting them into swamps. Little is known about its character or thickness, but the alluvium must be relatively thin. Most of it overlies the Tuscaloosa, occurring at altitudes below the Tuscaloosa-Barnwell contact. Its age is Quaternary, and the heavily forested condition over much of it suggests that there has been little addition of sediment during modern time.

Character of the Deposits

Lenslike deposits of white kaolin, in places mottled with yellow and red iron oxide, occur sporadically in all parts of the Tuscaloosa formation in this area. They commonly grade into the enclosing clayey sands, but some contacts are sharp. Most of the deposits are too sandy and micaceous to be of present economic interest, but the purer bodies are the basis of the kaolin industry in Georgia. Most of the purer raw kaolin from these deposits averages (dry basis) 44 to 47 pct SiO_2, 37 to 41 pct Al_2O_3, 1 to 2 pct TiO_2, less than 1 pct Fe_2O_3, and extremely small amounts of lime, magnesia, soda, and potash.[10] The freshly cored material contains 18 to 22 pct free moisture. Variations in analyses of the raw kaolin, given in the reports cited herein, are caused chiefly by differences in the proportions of fine sand and mica in the kaolin.

In the mining area, the kaolin is termed hard, semihard, or soft according to its toughness when air-dried. Kaolinite is the chief constituent, with quartz and muscovite the main impurities, and iron and titanium oxide minerals, zircon, and tourmaline the most persistent minor impurities. The deposits range from a few feet to perhaps half a mile in major dimension. A single deposit may consist of soft, semihard, or hard kaolin, or it may contain a lower layer of soft kaolin overlain by a layer of harder kaolin. Where two layers occur, there is commonly a sharp line of contact between them. Klinefelter and others[10] have shown that the particle size of the hard kaolin is finer than that of the soft kaolin.

The deposits contain a few concretions of iron sulphide ranging in size from scarcely visible pellets to several inches across, and the kaolin adjacent to the concretions is brown, apparently carbonaceous. Weathering converts the concretions into limonitic balls usually hollow or containing partly oxidized sulphide. In places, the concretions are attached in sinuous, linear groups that are mostly vertical. Those that occur at the top of a bed of kaolin, under relatively thin overburden, have been leached leaving sinuous rusty cavities partly filled with inwashed sand. These are not fossil tree roots, a possibility implied by Smith.[9]

Yellow, iron-oxide stains and black organic stains are fairly common in outcrops of the kaolin deposits and in their uppermost parts where the overburden is very thin. Such stains are clearly of post-Tertiary origin, as they diminish to extinction with increase in the thickness of cover. Drilling has shown that the iron-oxide stains, which are derived from the weathering of the iron sulphide and are the more persistent, are rarely found under 50 ft or more of overburden, and are not prominent if the cover is only 25 ft thick. They are not to be confused with the vivid brick-red iron-oxide stains, which, in many places, occur at considerable depth, and show no relation to the present surface or to the unconformity at the top of the Tuscaloosa. These red iron-oxide stains appear to be primary. Careful attention has been given to both the yellow and red stains and other characteristics of the upper part of the Tuscaloosa, but the writer has seen no clear evidence of subaerial erosion as the origin of the unconformity at the top of the Tuscaloosa, and marine erosion seems the probable cause.

Fig. 3—Bottom end of inner core barrel, showing brass centering studs and 6-in. dry-plug shell.

Pisolitic bauxite, commonly overlain by an extremely hard variety of kaolin known locally as chimney rock, occurs in some places on kaolin at the unconformity above the Tuscaloosa. These occurrences evidently identify truncated kaolin lenses, as sporadic bodies of bauxite are found, in drilling, as much as 30 ft below the unconformity and invariably in the interior of kaolin deposits rather than on their surface. Such buried bauxite is mostly white, but some of it is mottled brick-red and green. The occurrence of the buried bauxite, in thick bodies of kaolin containing no clear evidence of subaerial erosion, strongly indicates that there is no relation between the origin of the bauxite and that of the unconformity. In fact, they appear to be widely different in age—the unconformity being early Tertiary or pre-Tertiary and the bauxite being post-Tertiary and related to weathering.

The only organic remains that have been found in the Tuscaloosa occur in, or immediately above or below, a few of the kaolin deposits. The remains are leaves and grasses that occur in thin beds of lignite, in zones of brown carbonaceous sand and clay as much as 6 ft thick.

Problem of Origin

It has been generally agreed, since the first investigation of Georgia kaolin by Ladd,[9] that the erosion of weathered rocks of the Piedmont furnished the sand and kaolin of the Tuscaloosa formation. The vast amount of haphazardly piled material in the Tuscaloosa indicates rapid erosion and transportation. The debris was evidently deposited in coalescing deltas and alluvial fans along the Cretaceous shore line, and in part redistributed by stream and ocean currents, as shown by an abundance of minor unconformities. The lenses of kaolin

Fig. 4—Bottom end of assembled core barrel, showing general design of the bit including waterways and reaming ring.

were deposited, in pools and lakes of fresh[4] or salt[11] water, nearly isolated from the currents.

Even with scant evidence, a few arguments have developed. Veatch[4] inferred that the weathering that made the debris available for erosion had been in progress since Cambrian time and that only a few feet of red-stained saprolite would have developed in the Piedmont during this time. Thus, he minimized the development and pigmenting power of natural iron oxide in attempting to explain the lack of color in the kaolin deposits. Neumann,[11] in considering the Tuscaloosa kaolin deposits of South Carolina, doubted that long weathering would have developed so little red color, and his objection is sustained by the occurrence of the largest area of mafic crystalline rocks in Georgia, which weather deeply and vividly red, immediately northwest of the kaolin-producing area.[12] Neumann accounted for the lack of red color in the kaolin by assuming that heavy plant growth, which was on a pre-Tuscaloosa Piedmont surface reduced to a peneplain, provided organic acids that leached iron from the rocks as they were weathered.

Since these ideas have developed on the hypothesis that weathering was active continuously in the Piedmont region from Cambrian to Upper Cretaceous, it would be well to examine the underlying premise. The geologic map of Georgia[12] shows dikes of Triassic diabase as well as bodies of Carboniferous granite in the crystalline rocks overlapped by the Tuscaloosa and younger formations. These igneous rocks do not cut the Coastal Plain formations and consequently they must have been a part of the crystalline "complex" eroded to furnish the Coastal Plain sediments. Weathering of genetic importance to the Tuscaloosa, therefore, must have started not earlier than the end of the Triassic, and recent evidence cited by Richards[13] tends to limit further the possible length of time. This evidence involves the discovery of up to 3000 ft of pre-Tuscaloosa and post-Triassic sediments in deep oil tests in eastern North Carolina. All of these beds may be Lower Cretaceous, or the lower 1400 ft may be Jurassic. Approximately equivalent beds are reported by Applin[14] in deep-well cores from other parts of the Coastal Plain, in Florida, Georgia, and Alabama. From this it appears that the Piedmont of Georgia may have been part of a relatively high region undergoing erosion during the Lower Cretaceous if not the Jurassic. The basis for inferring a long pre-Tuscaloosa period of saprolite development, even more extensive than that which produced the Piedmont of today, thus seems to disappear.

Similarly, the basis for disagreement regarding a difference in origin between the soft and hard kaolin seems to disappear in view of conclusive tests by the Bureau of Mines[10] showing no fundamental difference except in particle size, and the occurrence of all grades of semihard kaolin, qualitatively bridging the gap between the extremes. Where a deposit consists of a lower layer of soft kaolin and an upper layer of hard kaolin, it is evident that there first was deposited material of one size and later material of a finer size, with an intervening period of no deposition. A pause in sedimentation seems more likely than continuous sedimentation, with separation according to particle size, as suggested by Smith.[9] Evidence for such a pause is afforded by the usual line of separation between the layers and by laboratory evidence cited by Gongwer,[14] who states that there is no separation of coarser from finer particles during the settling of ground clays suspended in water.

The earlier suggestion by Stull and Bole[15, 16] that silicic acid derived from fullers earth has hardened deposits originally soft is most inadequate in view of the normal stratigraphic relations described herein. The Twiggs clay (fullers earth) overlies the Tuscaloosa in the entire area except where it has been carved out by the modern streams. Consequently, all of the kaolin deposits near the top of the Tuscaloosa have had the same environment probably until the Pleistocene. In spite of this, deposits of both hard and soft kaolin occur in places with a cover of fullers earth, and in other places without it, indicating that neither the superposition of the fullers earth nor its partial removal have influenced the hardness of the kaolin.

Quite recently Bridge[17] has directed attention to the unconformity at the top of the Tuscaloosa in connection with the origin of the bauxite deposits of the Southeast. He believes that the bauxite-containing kaolin deposits are not actually within

Fig. 5—Hydraulic hand pump used to remove core from inner barrel.

the uppermost part of the Tuscaloosa formation, but instead "rest on and are seemingly a part of" that formation, supposedly being part of a thin veneer of transported materials deposited on an early Tertiary erosion surface "almost contemporaneously with its formation," and largely removed by later erosion. However, all of the evidence seen by the writer in open-cut mines and in cores and cuttings from hundreds of drill holes, many reaching more than 100 ft below the unconformity, shows the uppermost kaolin deposits and associated sediments to be integral parts of the Tuscaloosa. They are not different in age, in origin, or in any characteristics other than the bauxite cores that a very few of them contain and the bleaching or brightening effect of weathering.

Perhaps the prominence of the unconformity has obscured the relation of the bauxite-bearing kaolin bodies to the overlying Twiggs clay and its calcareous beds. It is well known that iron sulphide commonly occurs in many of the kaolin bodies in all parts of the Tuscaloosa and that it has been oxidized only in the uppermost bodies within about 30 ft of the Twiggs clay or the position from which the Twiggs clay has been removed by post-Tertiary erosion. The oxidation appears to be associated strictly with post-Tertiary weathering, as mentioned above. Consequently, any of the uppermost kaolin bodies that were unusually rich in iron sulphide could have developed appreciable amounts of aluminum sulphate through reaction of natural sulphuric acid with the kaolin, and prompt reaction with calcium carbonate brought by ground water from the overlying Twiggs clay could have precipitated aluminum hydroxide. The calcium sulphate produced may have moved away in the ground water, or it may have been deposited with the hydroxide and subsequently leached. Either type of transport would result in some open structure, probably accounting for the occasional total loss of water circulation when the core drill penetrates bauxite.

To the exploration geologist or engineer, the importance of an adequate explanation of origin of the kaolin deposits lies in its application to the problems of discovery. The difference in the grade of the known deposits, plus the occurrence of more than one grade of kaolin in some of them, make it obvious that the most we can expect of a genetic theory is to indicate geologic associations or geographic trends favorable to the occurrence of kaolin lenses in the Tuscaloosa regardless of their specific character. The sketchy explanation thus far advanced provides no assistance.

A new approach might help. If there was no long pre-Tuscaloosa peneplanation and rotting of crystalline rocks, then it is unnecessary to account for deeply red-stained source material. The pell-mell accumulation of coarse sand and clay in the Tuscaloosa reflects a transgressing sea and steep stream gradients, with resulting vigorous erosion that could provide sediment whether or not thorough rotting had occurred. The debris fed to the streams may have been disintegrated rather than leached rock, and further disintegration during transport would have promoted gravity separation of the heavier iron-bearing minerals, from the feldspars and quartz, before oxidation had reached a strongly pigmenting stage. Thus, the sediment that finally reached the lower courses and mouths of the principal streams may have been largely arkosic sands, parts of which were fairly free of iron-bearing minerals.

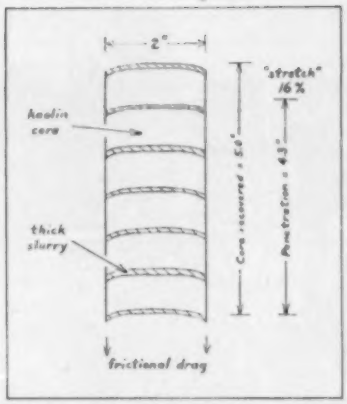

Fig. 6—Transverse shear planes developed in kaolin core.

The final decomposition of the feldspars may have occurred in these alluvial and deltaic deposits, adjacent to the lagoons in which the newly formed kaolin was subsequently deposited during redistribution of the sediments by flood and ocean currents. An origin of this sort would help to explain not only the lack of color but also the presence of sharply angular quartz grains in the smooth, homogeneous kaolin. The angularity of such grains undoubtedly reflects interlocking rock texture, probably an interlocking with feldspar that decayed after reaching the shore line or an adjacent area.

But it is not enough to explain the kind of source material and the mode of transport. To be useful, a genetic theory must take into account the character of the Tuscaloosa shore line and its currents. It must explain the relative abundance of kaolin deposits in the area here considered, from the base of the Tuscaloosa to the highest part exposed. It should indicate, if possible, preferred trends within and from this area, so that prospecting may be focused on favorable parts of the Tuscaloosa that are covered by the younger formations. If any trends are apparent, and if they can be adequately explained, clues may be provided for the discovery of others that are obscure.

Prospecting Methods and Equipment

Until recent years most of the prospecting in the Georgia kaolin country was done by hand boring and the digging of test pits. Various types of screw auger bits were used with ½-in. or ¾-in. pipe in short sections. The bit could be sunk only a few inches at each pass and could be pulled only with the greatest difficulty by three men, unless a tripod were set up after the penetration of as little as 15 ft of kaolin. Samples were contaminated with sand and colored clay from the overburden, and loose, water-bearing sand immediately above the kaolin often choked holes before sufficient depth was reached. A few power drills of auger type had been used but were unsatisfactory because of disturbed and contaminated samples and poor control of footage sampled.

Fig. 7—Kaolin-prospecting outfit, including Failing seismograph drill, supply truck, and arrangement of core barrel for discharging core.

Systematic, deep drilling with high recovery of relatively undisturbed core was started in the latter part of World War II and is rapidly gaining favor. There are now about ten rigs in operation, and the number is likely to increase. Seismograph drills with N rods are used, with one exception, and all operators have adopted a double-tube core barrel, with special bit, constructed so as to permit the core to be lubricated by the water without being greatly reduced in size or washed away. This barrel and bit constitute an ingenious tool peculiarly adapted to the difficulties involved. It was reportedly developed by Lewis C. Lindsay, of the Pennsylvania Drilling Co., who was probably the first to successfully carry on the deep testing of kaolin in the Georgia field, and it is known as the Lindsay barrel. The kaolin operators obtain repairs and replacements at the Kitchens and Harbuck machine shop in Americus, Ga. So far as the writer is aware, the barrel is not available anywhere as an open-stock item.

The inner barrel is of 2-in. tubing and must remain rather closely centered over the bit to insure that the core will enter perfectly at the beginning of the run. This is accomplished with four brass studs, arranged as shown in Fig. 3, which permit little sway of the inner barrel when in operation. The lower 6 in. of the tube is threaded for removal, Fig. 3, and is known as the dry-plug shell. As a core-lifter cannot be used with such plastic material as wet kaolin, the core is held in the barrel by cutting the last 6 in. dry, with increased drill-head pressure, and this lower part of the core (dry plug) must be removed from the shell with a special screw-driven piston. The remainder of the barrel is unloaded as described below.

The bit is of saw-tooth design, with six broad chisels, built of hard alloy, supported by the end of the outer barrel and a 2-in. ring that guides the core into the inner barrel. Spaces between the teeth, the ring, and the outer barrel are the waterways, as shown in Fig. 4. These feed the water directly to the cutting teeth, and a gap of only about 1/16 in. between the ring and the end of the inner barrel permits the water to lubricate the core without remaining in contact with it long enough to erode. The teeth cut ample outside clearance, but the inside clearance is spaced wide to permit the ring to ream the core to the exact size of the inner barrel. After each run the barrel is disassembled, and, after the dry-plug shell is removed, the core is pumped from the inner barrel with a Baker hydraulic hand pump, coupled at the dry-plug connection as shown in Fig. 5. Thus, the barrel discharges from the top, permitting a more orderly handling of core.

Deposits consisting of hard and semihard kaolin give the same difficulty, because of blocking, as do fractured rocks in diamond drilling, but with the kaolin it may result in core loss of 12 to 22 pct of the penetration, even with careful and experienced operation. Soft kaolin, on the other hand, commonly yields excess core measurement owing to closely spaced transverse shear planes, as shown in Fig. 6. These are caused by the adherence of the plastic kaolin to the ring in the bit, thus cutting a "biscuit" each time the ring is filled, and the biscuit rotates with the bit until pushed up into the inner barrel. During the rotation the shear plane below the biscuit admits drilling water, forming a thin sheet of slurry that may contain impurities introduced with the water. These probably would be sand, montmorillonite, and calcite derived from the Twiggs clay in the overburden. The length of the core is extended by these sheets of slurry, and the total "stretch" commonly ranges from 15 to 20 pct of the penetration.

Drilling technique differs somewhat according to the hardness of the kaolin, and the operator must determine for each deposit the most suitable drill-head pressure and rate of water circulation. All parts of the barrel must be washed between runs, and thrust bearings, which are used in the head, must be replaced frequently. Various types of fish-tail bits are used in overburden, and the writer has successfully used 4-in. flush-coupled casing where the limestone beds in the Twiggs clay are cavernous. A complete outfit is shown in operation in Fig. 7, and the work is frequently carried on with the aid

Fig. 8—Fresh split cores of kaolin arranged for inspection and sampling.

of a bulldozer, which cuts benches on steep slopes and plows drillways through the dense growth. The cores recovered in this work may be removed in standard core boxes for laboratory tests, or they may be examined and sampled immediately, see Fig. 8, to reduce bulk and remove obvious contamination.

Outlook for Discovery

Although the size of the kaolin-producing area is quite large, there is a decided difference in outlook between different parts of it. The outlook involves not merely the geologic possibility of the occurrence of kaolin lenses, but also accessibility for prospecting and mining, and possible relation between the depth of overburden and the size and grade of deposits that might be found. Although lenses of kaolin as thick as 50 ft[2] have been found, most of those mined have averaged nearer 20 ft; and although overburden of the order of 100 ft in thickness has been stripped in rare instances, most of it has been less than 60 ft thick, and less than half that amount in the smaller mines. Serious troubles resulting from ground water, particularly in the winter and spring, are encountered in openings in low ground near the swamps and near many of the smaller tributaries.

In view of these general facts as well as the exploration problems involved, the proportionate parts of the area in their relation to prospecting and mining are about as shown in Fig. 2. Of the total of 445 sq miles, about 100 sq miles or 22 pct is in the higher ridges in which all of the overburden, even if kaolin were found at depth, would exceed 75 ft, much of it being substantially more than 100 ft. At the other extreme, the ground that is unfavorably low includes 75 sq miles or 17 pct alluviated swamps and 40 sq miles or 9 pct low, sandy, water-bearing flats generally indicating sandy, easily eroded underlying material.

The remaining 230 sq miles, or 52 pct, of the area is comparatively favorable for prospecting or mining, or both. This part must be reduced still further, however, because many properties have been proved barren by prospecting carried on through the years, and because stream erosion has provided enough exposures on many other properties to show that no large deposits of good grade can be present under thin or moderate overburden. There is no way of closely estimating the extent to which these factors reduce the 52-pct part of the area shown in Fig. 2 as having favorable mining conditions. The full extent and significance of past prospecting are unknown as information is not freely exchanged among the operators, and the extent of dependably indicative natural exposures also is unknown because of a lack of geologic mapping of pertinent features. It may well be, however, that if it were possible to have the advantage of all previous prospecting as well as the results of very detailed areal mapping, it would be found that 25 pct to 50 pct of the 52-pct part of the area actually has no possibility of the discovery, at economic depth, of deposits large enough and good enough to sustain the industry in its present scale of operation.

This outlook need not give rise to pessimism concerning long-range reserves. It merely indicates that the possibilities are not scaled in proportion to the size of the area. Deposits yet to be discovered in this mining area of 445 sq miles will be found mostly in parts of it making up 115 to 175 sq miles in the total. To develop new reserves in these parts will claim an increasing amount of the attention, which, until recent years, has been given almost entirely to mining and milling. With adequate guidance, most of the work can be devoted to relatively favorable ground, an approach now in use in the area; but without guidance, it may be necessary to drill all property that can be leased, another current approach. Regardless of the approach or of the work involved, the industry is never likely to fall back on treating low-grade mixtures of sand and kaolin as long as more deposits of high-grade kaolin can be found.

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Contribution of Geophysical Surveys to the Discovery of Stilfontein Gold Mine in South Africa

by Oscar Weiss

STILFONTEIN and surrounding areas gave negative results in all prospecting attempts since about 1904 when Goerz and Co., a forerunner of Union Corporation Ltd., first drilled in the region and on the farm Stilfontein. Subsequent efforts by African and European Investments Co. and Anglo American Corp. from 1934–37 were completely unsuccessful. Holes drilled by these companies on the farms Rietfontein, Hessie, and Palmietfontein were stopped in the Lower Witwatersrand system without finding payable reefs.

The results of gravimeter, ground magnetometer, and aerial magnetometer surveys are presented in the area, in and around the new Stilfontein Gold Mine, in the Klerksdorp District of the Transvaal in the Union of South Africa. The gravimeter and ground magnetic surveys were completed in 1947–48. The gravity anomalies suggested a block of Upper Witwatersrand quartzites faulted-up between denser rocks of dolomite and Ventersdorp lava. Boreholes S.T. 1, 2, and 3 were drilled in 1948 and, after penetrating the dolomite and Ventersdorp lava, entered Upper Witwatersrand quartzites and intersected the Gold Estates Reef and Vaal Reef. Subsequent drilling delineated the suboutcrop of the Vaal Reef and determined the main structure of this horizon. The gold content of the Vaal Reef was highly payable and shaft sinking is now in progress. The Stilfontein Gold Mining Co. has been formed and, up to date, £5,000,000 capital has been raised for plant, shaft sinking, and development. The payable Vaal Reef horizon extends further south from Stilfontein, the reef occurring at increasing depths. It is possible that at least another mine may be established on these deeper horizons.

The farm Stilfontein 39 is situated in the Klerksdorp District of the Transvaal. This farm and the surrounding areas have been subjected to repeated programs of prospecting dating back to about 1904, when Goerz and Co., the forerunner of Union Corporation, Ltd., first drilled on the farm and in the surrounding areas. From 1934–37, numerous boreholes were drilled on the neighboring farms, Rietfontein, Hessie, and Palmietfontein, by African and European Investment Co. and Anglo American Corp. All these efforts were completely unsuccessful, and nobody suspected any possible gold-bearing area on Stilfontein until about 1947, when a gravity traverse run by B. D. Maree on the main road, showed a negative gravity anomaly. During 1947–48, the writer's organization completed gravimeter and magnetic surveys on Stilfontein and Rietfontein. An area of negative gravity anomalies was mapped, and it was suggested that this could be caused by blocks of Upper Witwatersrand quartzites, of the average density of 2.65, faulted up between dolomites and Ventersdorp lavas, the density of both of these rocks being 2.8.

Fig. 1 shows the geology of the area as mapped by L. T. Nel of the Geological Survey of South Africa. The boreholes on Stilfontein, with the exception of a single hole of Goerz and Co., were drilled after the completion of the geophysical survey. The grouping of the first boreholes S.T. 1, 2, 3, 4, 5, and 6, clearly shows that these were located in the zone of negative gravity anomalies. Fig. 2 shows the gravity anomaly contours.

Fig. 3 shows two sections across the gravity anomaly, together with the corresponding geological sections as obtained from boreholes. The close relation between gravity values and thickness of dolomite plus Ventersdorp lavas is striking. The two latter formations having the same density (2.8), act as one mass as far as gravity effects are concerned.

Fig. 4 shows the magnetic anomalies observed on the ground by vertical magnetometers and at 500 ft above mean ground level by aerial magnetometer. The latter are anomalies of the total magnetic intensity. The magnetic results show that, on the farm Rietfontein and on the northern half of Stilfontein, Lower Witwatersrand magnetic shales were to be expected at relatively shallow depths. As the strongly

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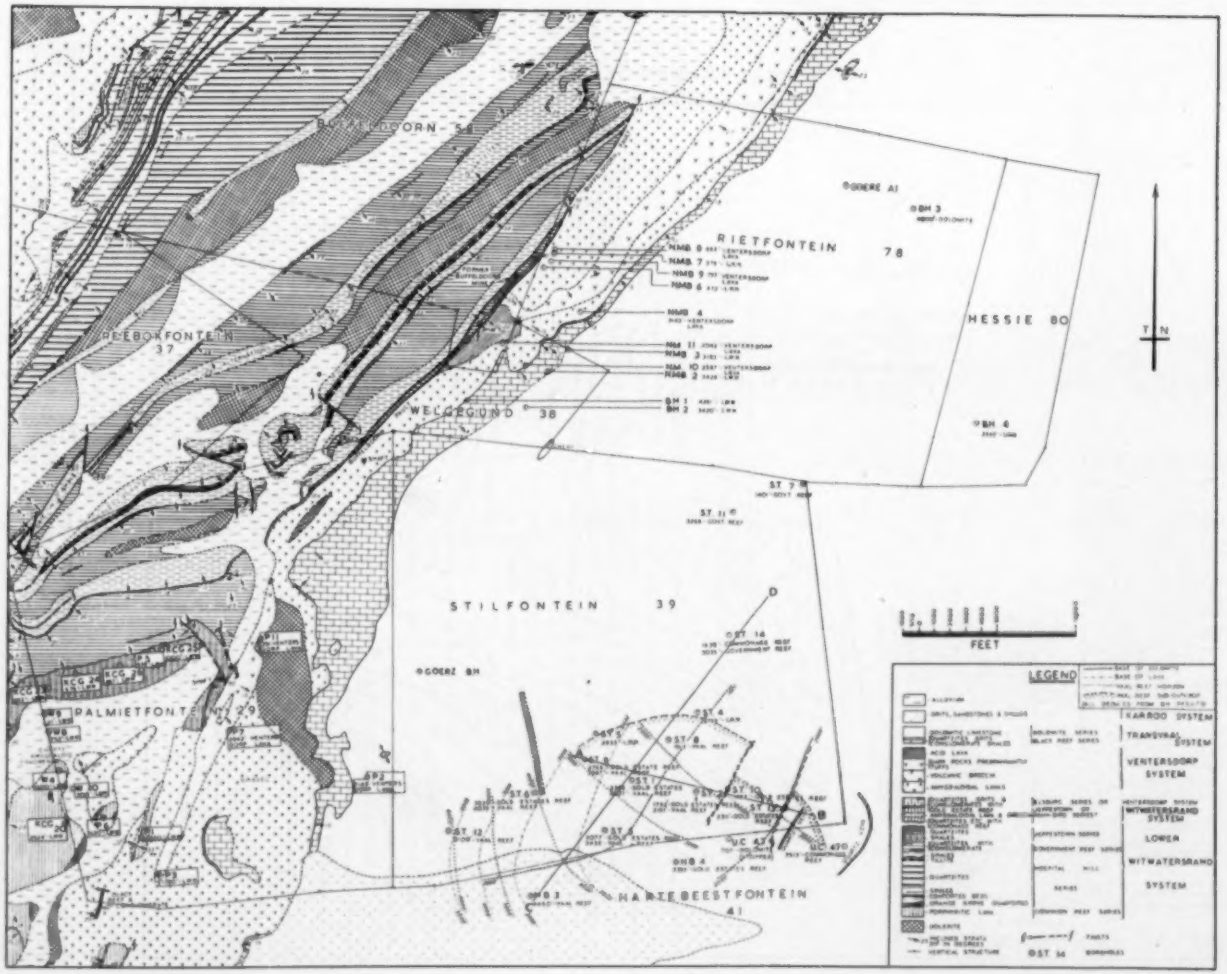

Fig. 1—Geological plan of Stilfontein region. Geology after Louis T. Nel.

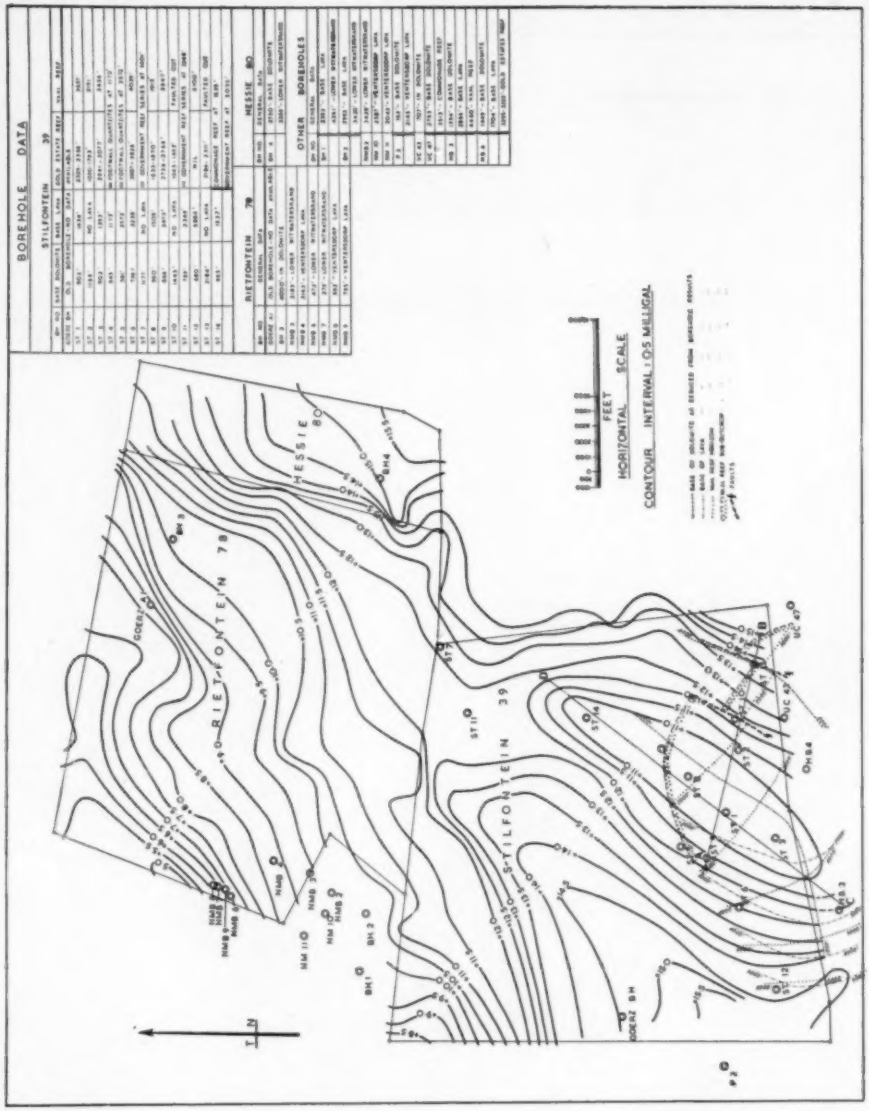

Fig. 2—Gravimeter survey of Stilfontein.

magnetic shales of the lower Witwatersrand system[1] are in the Hospital Hill series and in the Government Reef series, below any known gold-bearing pay horizons, the existence of magnetic anomalies beneath the dolomite and Ventersdorp systems was an indication of the probable absence of pay horizons. At the same time the lack of magnetic anomalies in the southern portion of Stilfontein suggested the absence of major upthrows of the Lower Witwatersrand magnetic shales.

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The geological plan, see Fig. 1, shows that the oldest formation of the area, the contorted beds near the base of the Witwatersrand system, outcrop in the northwest corner of the plan. Moving in a southeasterly direction from this corner, the Witwatersrand system is faulted up repeatedly by strike faults as shown by the repetition of Government Reef shales and tillites, so that, in this direction, the outcrops do not show horizons higher than the Government Reef series in the Witwatersrand system. This system is overlain by Ventersdorp lavas and sediments and by black reefs and dolomites of the Transvaal system. This dolomite covers the entire area of

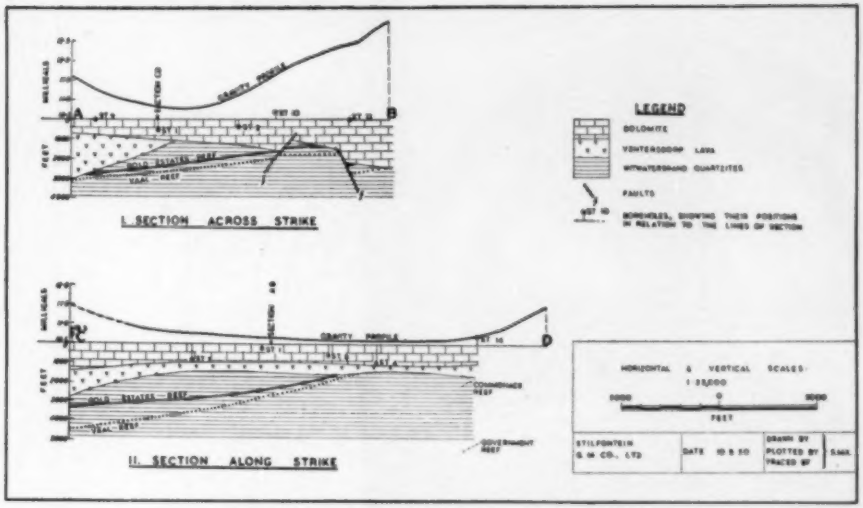

Fig. 3—Geophysical survey Stilfontein Gold Mine, Sections AB and CD.

Stilfontein with the Ventersdorp lava and black reef outcropping in a small portion of the northwest corner of this farm.

Starting again from the northwest corner of the geological plan and moving southward, we again find faulted repetitions of the Government Reef series, but the Witwatersrand system builds up to the Jeppestown series and even higher in the extreme south corner of the plan, where the Elsburg series is outcropping. As the Main Reef horizon of the Rand proper, near Johannesburg, occurs above the Jeppestown shales, exploration drilling by Anglo American Corp. (1934–37) in this part of the plan, on the farm Palmietfontein, was intended to intersect the Main Reef horizon. Unfortunately, in spite of systematic drilling, no pay reefs of any kind were found and all the holes stopped in Lower Witwatersrand beds (LWW).

On the farm Rietfontein, all the NMB holes were drilled by African and European Investment Co.'s subsidiary (New Machavie Mine) and by Anglo American Corp., during 1934-37, boreholes (B.H.) 1, 2, 3. In addition, Goerz A.1 hole was drilled in about 1903. The purpose of all the NMB holes and of boreholes 1 and 2 was to find the extension of the old Buffelsdoorn mine, which worked rich conglomerate beds correlated with Government Reefs. None of this drilling was successful.

Boreholes Goerz A.1 and Anglo American Corp.'s boreholes 3 and 4 (on farm Hessie) were located to find the Main Reef Horizon. These holes were also failures.

It seems that the system of up-throw faults continues to the southeast in the areas tested by these holes. It is interesting to note that the farm Stilfontein was completely ignored by the companies who sponsored the drilling programs.

The gravity anomaly plan shows that, starting from the Ventersdorp lava outcrops in the northwest corners of Stilfontein and Rietfontein, the gravity anomalies increase as the Ventersdorp lava, black reef and dolomite is piling up, but the southeastern half of Stilfontein is an exception. Here, after reaching the value of 14 milligals, the gravity anomaly decreases to a minimum of 11 milligals and rises again to 15 milligals in the extreme southeast corner of the farm. There is thus a negative anomaly of about 3 to 4 milligals and the total thickness of the Ventersdorp lava and dolomite is less in this zone of negative anomalies than in the surrounding areas. Furthermore, as the density of Lower Witwatersrand magnetic shales is also about 2.8, no negative gravity anomalies could occur if the lava and dolomite were underlain by such shales. It was therefore concluded that the negative gravity anomaly was caused either by Upper Witwatersrand quartzites (density 2.65) or by a granite mass (density 2.63). As the aim of the prospecting was to test by drilling Upper Witwatersrand horizons

Table I. Vaal Reef Intersections in Boreholes of Stilfontein Gold Mining Co.

BOREHOLE NO.	THICKNESS OF VAAL REEF	GOLD VALUE PER INCH	TOTAL VALUE INCH-DWTS	REMARKS
STILFONTEIN 39				
S.T. 1	5·75 INCHES	17·5 DWTS.	101 INCH-DWTS.	
	20·75 "	3·1 "	65 "	1st DEFLECTION
	5·00 "	12·9 "	99 "	2nd "
S.T. 2	3·00 "	31·2 "	94 "	
	12·25 "	20·9 "	256 "	DEFLECTION
S.T. 3	7·25 "	103·4 "	750 "	"
S.T. 4	BEYOND VAAL REEF HORIZON			
S.T. 5	BEYOND VAAL REEF HORIZON			
S.T. 6	4·90 INCHES	34·6 DWTS.	162 INCH-DWTS	
	5·75 "	22·3 "	129 "	DEFLECTION
S.T. 7	BEYOND VAAL REEF HORIZON			
S.T. 8	7·50 INCHES	80·9 DWTS.	607 INCH-DWTS	
S.T. 9	9·50 "	149·4 "	1419 "	
S.T. 10	VAAL REEF FAULTED OUT			
S.T. 11	BEYOND VAAL REEF HORIZON			
S.T. 12	13·40 INCHES	5·0 DWTS.	67 INCH-DWTS.	
	13·60 "	2·65 "	35 "	1st DEFLECTION
	10·90 "	24·93 "	271 "	2nd "
S.T. 13	VAAL REEF FAULTED OUT			
S.T. 14	BEYOND VAAL REEF HORIZON			
HARTEBEESTFONTEIN 41				
HB. 3	3·90 INCHES	51·2 DWTS.	208 INCH-DWTS.	
HB. 4	VAAL REEF NOT INTERSECTED DUE TO DYKE AT 1484'			
UC. 43	STOPPED IN DOLOMITE			
UC. 47	BEYOND VAAL REEF HORIZON			

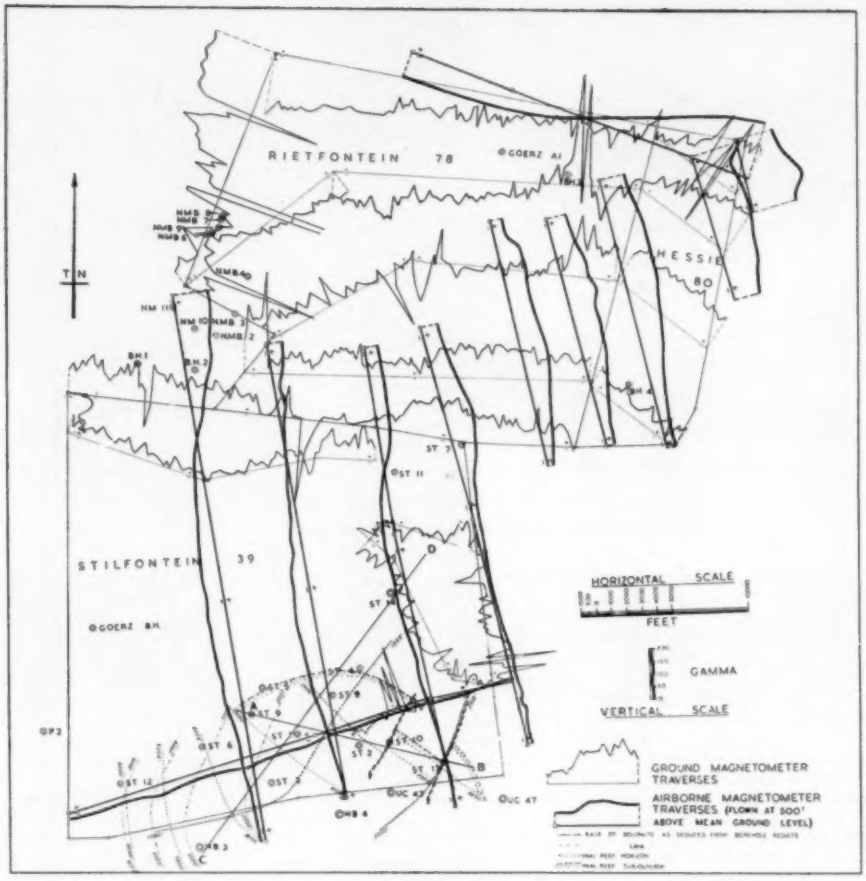

Fig. 4—Magnetic survey of Stilfontein.

for reefs, the obvious sites for such tests were located in the minimum zone of the negative anomaly. The grouping of the holes S.T. 1, 2, 3, 4, 5, 6, 8, 9, and 14 in the negative anomaly area proves the practical following up of the above ideas. All these holes intersected Upper Witwatersrand beds. Boreholes S.T. 7 and S.T. 11 were located outside the negative gravity anomaly, and these holes went into Government Reef, i.e., into Lower Witwatersrand beds. It should be mentioned that the last figure of footage next to any borehole gives the depth at which the hole was stopped.

Table I gives the widths and gold values intersected on Stilfontein.

The approximate contours of the Vaal Reef are shown in Figs. 1, 2, and 3; and, as can be seen, the reef extends southwards, although at increasing depths. It is very likely that at least another gold mine will be established in due course in the area south of Stilfontein.

On the completion of these holes, the Stilfontein Gold Mining Co. was formed with a capital of £3,500,000. To date, £5,000,000 has been raised, by means of share issues and loans, for shaft sinking, development and plant. The total share capital is 14 million 5-shilling shares, of which 11 million shares have been issued and the present market value of these is about £1 per share. A convertible unsecured loan has been obtained for £2,000,000 from London bankers and financial institutions.

Assuming of the order of 30 to 40 million tons potential ore reserves, we can expect a mine with the capacity of about 100,000 tons of ore per month and with a lifetime of about 30 to 35 years. The average grade, as a sheer guess, may be of the order of about 6 to 8 dwt per ton. Average cost per ton, allowing for the increasing costs of present times, should be about 3 dwt per ton, i.e. about 35 shillings per ton. Thus an average profit of 3 to 5 dwts, i.e., 36 to 60 shillings per ton may be expected. Taxation formula payable to the Government has not yet been settled.

Acknowledgment

The writer wishes to thank Jack Scott and Union Corp. Ltd., for permission to publish the technical data of this paper.

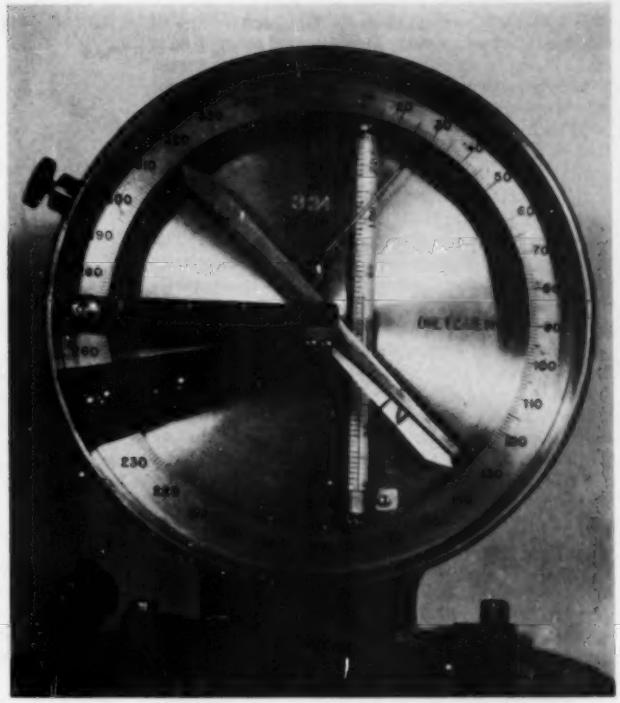

Fig. 1—Hotchkiss Superdip needle system.

The Hotchkiss Superdip As a Vertical Intensity Magnetometer

by W. A. Longacre

IN the geophysical exploration program of the Cleveland-Cliffs Iron Co. on the Marquette Range of Northern Michigan, the vertical intensity magnetometer has been used to obtain magnetic anomaly maps of large areas. A network of magnetic base stations has been established and the relative vertical intensity at each station measured carefully with respect to a prime base.

In the search for the relatively nonmagnetic soft red hematite ore, the magnetic exploration is indirect, involving the study of dikes, faults, contacts, and other structural features. It was found that the magnetometer, adjusted to a scale value of approximately 40 γ per scale division, was satisfactory for this type of exploration, although many magnetic anomalies were encountered that required the use of auxiliary magnets.

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The magnetic exploration for the harder type of ore, a mixture of specular hematite and magnetite, is much more direct. This ore is usually very magnetic, although large variations in the magnetite content do cause correspondingly large changes in the magnetic susceptibility. Some additional complicating factors are often present; the hard ore is frequently associated with magnetic beds of an iron silicate complex, occasionally with a conglomerate of iron formation material that may be quite magnetic, and almost always with sills and dikes of diorite. The latter material, while usually much less magnetic than the hard ore, is found to range in magnetic properties from nearly nonmagnetic to strongly magnetic.

The magnetic anomalies encountered in hard ore exploration are often very large and occasionally of such a complicated nature that interpretation becomes difficult. Since the ordinary vertical intensity magnetometer does not have the necessary range to permit measurement of the anomalies, the Hotchkiss Superdip was adopted for this phase of the exploration. It was considered desirable to continue mapping changes in the vertical component of the earth's magnetic field, so the Superdip was used with magnetic east-west orientation. However, since the anomalies measured by the Superdip were expressed in degrees, and the anomalies resolved by the magnetometer expressed in gammas, it soon became apparent that for better mapping and clearer interpretation it would be desirable to calibrate the degree scale of the Superdip in terms of gammas.

In a recent paper,[1] H. L. James of the U. S. Geological Survey described the use of the Hotchkiss Superdip oriented normal to the magnetic meridian and compared its performance with both Askania and Wolfson vertical intensity magnetometers. It was demonstrated clearly that Superdip data, taken with east-west orientation, correlate better with magnetometer data than does the data taken with the Superdip in the conventional magnetic meridian orientation.

Fig. 1 is a photograph and Fig. 2 a schematic representation of a carefully designed Hotchkiss Superdip needle system. The magnetic needle is pivoted at its center of gravity, and the magnetic poles are symmetrically positioned on the longitudinal axis of the needle. With the counterweight removed, the nonmagnetic needle is pivoted at its center of gravity. The two needles are clamped together firmly, the angle between them being adjustable.

The magnetized needle is of pole-strength m, magnetic length 2 l, and magnetic moment $M = 2\ m\ l$. The counterweight is at distance a from the pivot and has weight W. The angle between the two needles is Σ. The reading angle θ is measured clockwise from the upper vertical line through the pivot to the N-end of the magnetized needle. The vertical component of the earth's field is V. It is assumed that any self-consistent system of units is used.

The equilibrium equation of the instrument is given by

$$mV\ (2\ l \sin\theta) = Wa \sin(\theta - \Sigma)$$

or

$$MV \sin\theta = Wa \sin(\theta - \Sigma) \qquad [1]$$

$$MV \sin\theta = Wa\ (\sin\theta \cos\Sigma - \cos\theta \sin\Sigma)$$

$$\frac{MV}{Wa} = \cos\Sigma - \sin\Sigma \cot\theta$$

$$\cot\theta = \cot\Sigma - \frac{MV}{Wa \sin\Sigma} \qquad [2]$$

In eq 2, the reading angle θ is expressed implicitly as a function of the vertical intensity V.

The sensitivity of the Superdip is given by

$$S = \frac{d\theta}{dV}$$

Differentiating eq 2,

$$-\csc^2\theta \frac{d\theta}{dV} = 0 - \frac{M}{Wa \sin\Sigma}$$

$$S = \frac{d\theta}{dV} = \frac{M \sin^2\theta}{Wa \sin\Sigma} \qquad [3]$$

The sensitivity is large when $\sin\Sigma$ is small, but also depends on the reading angle θ. Eqs 2 and 3 may be combined to eliminate the term $Wa \sin\Sigma$, leading to

$$S = \frac{\sin^2\theta\ (\cot\Sigma - \cot\theta)}{V} \qquad [4]$$

The reading angle θ for which the sensitivity is maximum can be found by differentiating eq 4 and equating $\frac{ds}{d\theta}$ to zero. Thus,

$$\frac{ds}{d\theta} = \frac{1}{V}\ [\sin^2\theta\ (\csc^2\theta) + (\cot\Sigma - \cot\theta)\ (2 \sin\theta \cos\theta)\ ] = 0$$

$$\frac{1}{V}\ [1 + \cot\Sigma \sin 2\theta - 2\cos^2\theta] = 0$$

$$\frac{1}{V}\ [1 + \cot\Sigma \sin 2\theta - 1 - \cos 2\theta] = 0$$

$$\frac{1}{V}\ [\cot\Sigma \sin 2\theta - \cos 2\theta] = 0$$

$$\cot\Sigma \sin 2\theta = \cos 2\theta$$

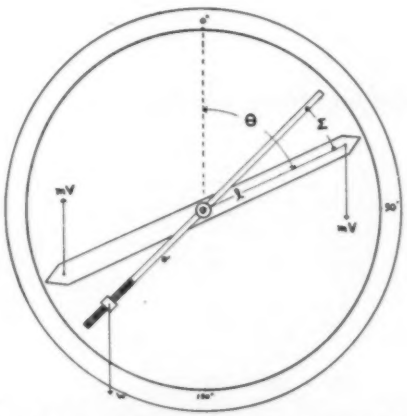

Fig. 2—Schematic representation of Hotchkiss Superdip needle system.

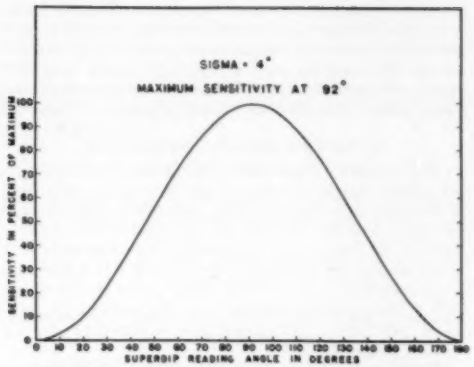

Fig. 3—Superdip sensitivity, a function of the reading θ.

$$\cot \Sigma \tan 2\theta = 1$$

$$\tan 2\theta = \tan \Sigma = \tan (180° + \Sigma) = \tan (360° + \Sigma)$$

$$2\theta = \Sigma = 180 + \Sigma = 360 + \Sigma$$

$$\theta = \frac{\Sigma}{2} \text{ (minimum)}$$

$$\theta = 90 + \frac{\Sigma}{2} \text{ (maximum)}$$

$$\theta = 180 + \frac{\Sigma}{2} \text{ (minimum)}$$

When $\theta = 90° + \frac{\Sigma}{2}$, the sensitivity is a maximum for any given field V and any given Σ.

The sensitivity of the Superdip as a function of the reading angle is given in Fig. 3.

Superdip Calibration

From eq 1

$$MV \sin \theta = Wa \sin (\theta - \Sigma)$$

$$V = \frac{Wa}{M} \frac{\sin (\theta - \Sigma)}{\sin \theta}$$

If it is assumed that the ratio $\frac{Wa}{M}$ remains constant for a given Superdip, then several methods of calibration are possible.

1—If magnetic base stations of known absolute vertical intensity are available, readings taken at these stations will permit the determination of the most probable value of the ratio $\frac{Wa}{M}$, and a calibration curve for the instrument can be obtained by simple calculation.

2—If a suitable Helmholtz coil is designed and calibrated, data could be taken at a station leading to the calculation of the absolute vertical intensity at the station as well as the value of the ratio $\frac{Wa}{M}$.

3—If a number of stations are located across an area of large anomaly and the relative vertical intensity of each determined carefully with a magnetometer, these stations could be occupied by the Superdip, and data obtained leading to a calibration curve. The calculations will be more dependable if the temperature of the Superdip is nearly constant and near the standard temperature to which all readings are corrected and the diurnal variation of the earth's field not appreciable during the experiment.

Base stations of known absolute vertical magnetic intensity were not available within a convenient distance. Since longer time intervals between stations would likely result in large temperature changes, and also large diurnal change in the magnetic field, it was decided that method 1 was not practicable. A suitable Helmholtz coil was not available, and since the design and construction of the coil promised to be a formidable undertaking with the facilities available, method 2 was not tried. Therefore method 3 was used in the calibration of the Superdip and forms the basis for this paper.

Calibration, Method 3

One of the magnetometer base stations was known to be near an area of high magnetic anomaly. In a traverse, across the anomalous area, seven stations were located so as to give a wide range of relative vertical intensity, the first being about 1000 γ higher than the base, the seventh being over 17,000 γ higher than the base value. At each station, wooden stakes were driven firmly into the ground in a triangular pattern; then a hole was drilled in the top of each stake to provide a firm and stationary location for each leg of the instrument tripod. The Superdip tripod legs were adjusted in length so that the Superdip needle system would occupy the same position in space at a station as had been occupied by the magnetometer system. This was important because of the probability of there being large horizontal and vertical gradients of magnetic intensity in a strongly magnetic area.

The anomaly in magnetic vertical intensity relative to the base was measured carefully at each station with a Ruska magnetometer and checked with an Askania magnetometer. Accurately calibrated auxiliary magnets were used at the higher level stations.

The Superdip, with Σ angle at 4°, was then used in occupying the base and the seven related stations. The circuit was made twice with multiple readings being taken at each station. Individual readings were taken as the weighted average of the end points of the first swing, the second swing, and the third swing; the end point of the second or reverse swing being doubly weighted. All readings were corrected approximately for temperature changes and for diurnal variations of the magnetic field.

Superdip calibration data for June 1949 are given in table I.

These data, by substitution in eq 1, lead to the following equations:

$$V_s + 0 \qquad = \frac{Wa}{M} \frac{\sin (58.3 - 4)°}{\sin 58.3°} = 0.95448 \frac{Wa}{M}$$

Table I. Calibration Data, June 1949

Station No.	4	4-1	4-2	4-3	4-4	4-5	4-6	4-7
Anomaly in Gammas, Relative to Sta. 4	0	1009	1971	3385	6914	10,317	13,820	17,474
Corrected Superdip Reading, deg.	58.3	69.6	82.1	101.8	137.3	151.9	159.6	164.4

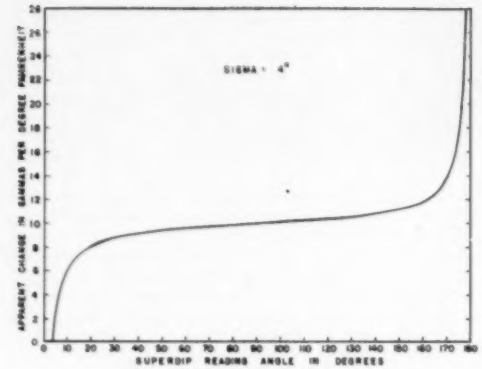

Fig. 4—Calibration curve, Superdip No. 334.

$$V_a + 1009 = \frac{Wa}{M}\frac{\sin(69.6-4)^\circ}{\sin 69.6^\circ} = 0.97162\,\frac{Wa}{M}$$

$$V_a + 1971 = \frac{Wa}{M}\frac{\sin(82.1-4)^\circ}{\sin 82.1^\circ} = 0.98789\,\frac{Wa}{M}$$

$$V_a + 3385 = \frac{Wa}{M}\frac{\sin(101.8-4)^\circ}{\sin 101.8^\circ} = 1.01214\,\frac{Wa}{M}$$

$$V_a + 6914 = \frac{Wa}{M}\frac{\sin(137.3-4)^\circ}{\sin 137.3^\circ} = 1.07316\,\frac{Wa}{M}$$

$$V_a + 10{,}317 = \frac{Wa}{M}\frac{\sin(151.9-4)^\circ}{\sin 151.9^\circ} = 1.12821\,\frac{Wa}{M}$$

$$V_a + 13{,}820 = \frac{Wa}{M}\frac{\sin(159.6-4)^\circ}{\sin 159.6^\circ} = 1.18513\,\frac{Wa}{M}$$

$$V_a + 17{,}474 = \frac{Wa}{M}\frac{\sin(164.4-4)^\circ}{\sin 164.4^\circ} = 1.24740\,\frac{Wa}{M}$$

By application of the method of least squares the most probable value of V_a was found to be 57,100 γ and the most probable value of $\frac{Wa}{M}$ found to be 59,780 γ.

Base 4 was known to be about 320 γ higher in magnetic level than the prime base, which has been assigned an arbritary value of 1000 γ. The calculated absolute vertical intensity at the prime base, about 56,780 γ, was thus a byproduct of the Superdip calibration. The normal value for the area in 1949, estimated from U. S. Coast and Geodetic Survey charts, was about 58,300 γ, indicating that the prime base had been located in an area where the magnetic vertical intensity was some 1500 γ below the normal value.

The experiment was repeated at the beginning of the 1950 field season. The method was the same as before except for minor changes in technique aimed at improving temperature corrections for the Superdip and improving the treatment of diurnal variations. The results were in fair agreement with the ones obtained previously. The comparison of measured values for 1949 and 1950 is given in Table II.

Table II. Comparison of Measured Values, 1949 and 1950

	1949	1950
V_4, γ	57,100	56,560
$\frac{Wa}{M}$, γ	59,780	59,360
Prime base, γ	56,780	56,240

Prime Base Absolute Vertical Field

Shortly after the 1950 calibration experiment, an absolute magnetometer of the flux-gate type was obtained. This instrument, manufactured by the General Electric Co. for the Navy Bureau of Ordnance, has been used in checking the degaussing of ships and is known as the Mark V, Model 4 portable magnetometer. It is supposedly accurate to about 100 γ. By careful orientation of the permeable unit, it is possible to measure any component of the earth's magnetic field.

Repeated trials at the prime base with the absolute magnetometer gave an average value for the absolute vertical intensity of 56,100 γ, with the individual trials ranging from 56,000 to 56,300 γ.

Superdip Calibration Curve

Magnetometer station values had been obtained by measuring the difference in magnetic vertical intensity between a field station and the prime base, and adding algebraically this difference in gammas to 1000. Thus, to a station 200 γ higher in magnetic level than that of the prime base would be assigned a value of 1200 γ. It was intended that Superdip data should lead to approximately the same station value as would be obtained by magnetometer observations.

The absolute vertical intensity at any station is expressed by eq 1 as

$$V = \frac{Wa}{M}\frac{\sin(\theta-\Sigma)}{\sin\theta}$$

For the Superdip being used, $\Sigma = 4^\circ$, and $\frac{Wa}{M} = 59{,}360$ γ. Thus,

$$V = 59{,}360\,\frac{\sin(\theta-4)^\circ}{\sin\theta}$$

The anomaly relative to the prime base is given by:

$$\Delta V = V - 56{,}240 = 59{,}360\,\frac{\sin(\theta-4)^\circ}{\sin\theta} - 56{,}240$$

The station value in gammas is then given by:

$$\text{Station value} = \Delta V + 1000 = 59{,}360\,\frac{\sin(\theta-4)^\circ}{\sin\theta} - 56{,}240 + 1000$$

$$\text{Station value} = 59{,}360\,\frac{\sin(\theta-4)^\circ}{\sin\theta} - 55{,}240$$

In the latter formula the only troublesome calculation is the evaluation of the trigonometric ratio. This ratio was determined for each integral degree from 4° to 179°. As long as the Σ angle is held unchanged, this calculation need not be repeated for subsequent recalibration of the instrument. The station value corresponding to a Superdip reading angle is obtained by multiplying the corresponding trigonometric ratio by the instrument constant $\frac{Wa}{M}$, and subtracting from this result the absolute vertical intensity at the prime base less 1000 γ.

To facilitate the use of the calibration data, a set of curves was plotted showing the station value as ordinate and the reading angle of the Superdip as abscissa, see Fig. 4. The extremes of the calibration curve were plotted on semilogarithmic paper; other intervals were plotted with simple and convenient ordinate scales.

Temperature and Superdip Readings

To investigate the theoretical effect of temperature changes on the Superdip, reference is made to eq 1

$$V = \frac{Wa}{M} \frac{\sin(\theta - \Sigma)}{\sin\theta}$$

At a station where V is fixed, a change in temperature would produce a change in the term $\frac{Wa}{M}$ and a consequent change in the reading angle θ. The differentials of the terms of the above equation are found, on the assumption that V and Σ remain constant. Thus:

$$O = \frac{Wa}{M} d\frac{\sin(\theta - \Sigma)}{\sin\theta} + \frac{\sin(\theta - \Sigma)}{\sin\theta} d\frac{Wa}{M}$$

$$O = \frac{Wa}{M} \frac{\sin\theta\cos(\theta - \Sigma)\,d\theta - \sin(\theta - \Sigma)\cos\theta\,d\theta}{\sin^2\theta} + \frac{\sin(\theta - \Sigma)}{\sin\theta} d\frac{Wa}{M}$$

$$O = \frac{Wa}{M}\left[\frac{\sin\theta\cos(\theta - \Sigma) - \sin(\theta - \Sigma)\cos\theta}{\sin^2\theta}\right] d\theta + \frac{\sin(\theta - \Sigma)}{\sin\theta} d\frac{Wa}{M}$$

$$O = \frac{Wa}{M} \frac{\sin\Sigma}{\sin^2\theta} d\theta + \frac{\sin(\theta - \Sigma)}{\sin\theta} d\frac{Wa}{M}$$

$$d(\theta) = \frac{\sin\theta\sin(\theta - \Sigma)}{\frac{Wa}{M}\sin\Sigma} d\frac{Wa}{M} \qquad [5]$$

If the change in the instrument constant is proportional to the change in temperature, it would appear that the change in reading angle caused by a small change in temperature is proportional to the change in temperature but is also proportional to the function sin θ $(\theta - \Sigma)$. The latter function has a maximum at $\theta = 90 + \frac{\Sigma}{2}$, the reading angle at which the Superdip is at maximum sensitivity.

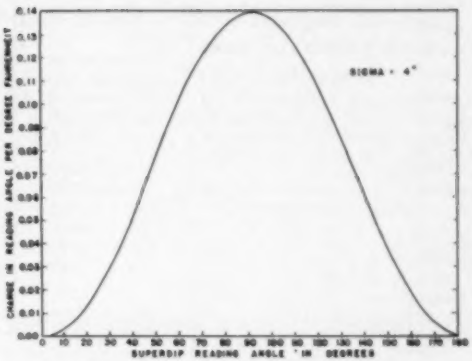

Fig. 5—Temperature correction in Superdip degrees per degree Fahrenheit as a function of the reading angle, Superdip No. 334.

Fig. 5 indicates the fallacy of using the same temperature correction per degree change in temperature for Superdip reading angles over the range of the instrument.

Another approach to temperature correction theory can be made by finding the change in indicated gammas per degree change in temperature.

If eq 5 is divided by eq 3, the apparent change in the vertical field caused by a change in the constant of the Superdip can be expressed thus:

$$\frac{d\theta}{dV} = \frac{\frac{\sin\theta\sin(\theta - \Sigma)}{\frac{Wa}{M}\sin\Sigma} d\frac{Wa}{M}}{\frac{\sin^2\theta}{\frac{Wa}{M}\sin\Sigma}}$$

$$dV = -\frac{\sin(\theta - \Sigma)}{\sin\theta} d\frac{Wa}{M}$$

Therefore, the apparent change of the vertical field caused by a change in temperature is proportional to the change in the instrument constant and is also proportional to the function $\frac{\sin(\theta - \Sigma)}{\sin\theta}$. The latter ratio is much more nearly constant in the range of reading angles from $\theta = 20°$ to $\theta = 160°$ than is the function sin θ sin $(\theta - \Sigma)$.

Table III. Partial Table, Calibration Data

$\theta°$	$\frac{\sin(\theta - 4)°}{\sin\theta}$	$\frac{Wa}{M}\frac{\sin(\theta - 4)°}{\sin\theta}$	Station Value	$\theta°$	$\frac{\sin(\theta - 4)°}{\sin\theta}$	$\frac{Wa}{M}\frac{\sin(\theta - 4)°}{\sin\theta}$	Station Value
4	0.000000	0.000000	−55,240	94	1.002442	39,565	4265
5	0.200239	11,890	−43,350	95	1.003667	39,580	4340
24	0.840887	49,920	−5320	124	1.044614	62,010	6770
25	0.847971	50,340	−4900	125	1.046408	62,110	6870
44	0.925330	54,930	−310	144	1.093577	64,910	9670
45	0.927607	55,070	−170	145	1.097187	65,130	9890
64	0.963541	57,200	1960	154	1.140588	67,700	12460
65	0.965036	57,280	2040	155	1.147149	68,100	12860
84	0.990232	58,780	3540	164	1.240835	73,660	18430
85	0.991461	58,855	3615	165	1.257898	74,670	19430
90	0.997564	59,215	3975	174	1.661258	98,610	43370
91	0.998782	59,290	4050	175	1.794274	106,540	51300
92	1.000000	59,360	4120	179	4.894041	290,450	241200

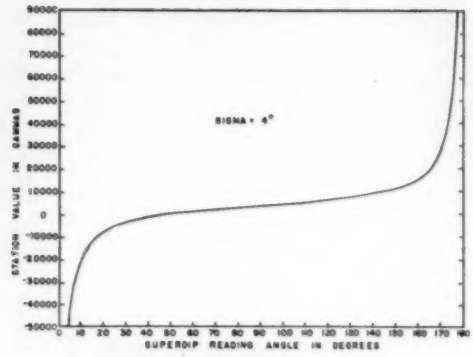

Fig. 6—Temperature correction in gammas per degree Fahrenheit as a function of the reading angle, Superdip No. 334.

Comparison of Figs. 5 and 6 would indicate the advantage of correcting for temperature changes of the Superdip in terms of gammas per degree change in temperature instead of change in reading angle per degree change in temperature. Either method can be used; in any case the actual temperature correction curve would have to be obtained by actual test of a given Superdip at various temperatures in a magnetic field whose time variations are measured carefully.

Reduction of Field Notes

As in magnetometer surveying, the use of base stations is essential in Superdip work. These bases are usually permanent installations in easily accessible locations with station values measured in gammas, as described previously.

In a given day's operation of the Superdip, a base station would be occupied at the beginning of the day, at the end of the day, and at several times during the working period. At all stations, both base and field, the reading angle, the temperature, and the time are recorded.

The reduction of the field notes is made in three steps. 1—The Superdip readings are converted to gammas by use of the conversion curve. 2—The temperature correction is applied to reduce all readings to a common temperature. 3—Correct for diurnal variation of the magnetic field and adjust the level of the results to the base station value. For example, after the first two steps, the indicated station value of the base, first observation, might be 80 γ lower than the true value. The second observation might indicate a value 60 γ too low. Thus 80 γ would be added to the first base observation, 60 γ to the second, and intermediate values to the intervening station observations, treating the diurnal effect as if it were a linear variation.

The final result for each field station is the measured station value, which is used in plotting profiles and isoanomalic contours. Part of an area could be surveyed with a magnetometer and another part of the area surveyed with the Superdip, but since the Superdip data were converted to equivalent magnetometer results, there would be no discontinuity in the mapping.

Accuracy of Station Values

No systematic attempt has been made to check the accuracy of results over the full range of the calibration curve. However, many magnetometer stations have been evaluated by means of the Superdip. In general, the correlation between the two instruments has been very good, especially for the middle portion of the range of the Superdip. The lack of agreement between station values as determined by the Superdip and by the magnetometer has seldom exceeded 15 γ for intermediate station values. A few stations have been checked with the Superdip where either low or high station values necessitated the use of auxiliary magnets with the magnetometer. In these cases, the lack of agreement between the instruments was somewhat greater, but the percent error was not inconsistent with the results at stations of intermediate value.

Conclusions

The Hotchkiss Superdip, oriented normal to the magnetic meridian, can be calibrated and used as a vertical intensity magnetometer of infinite range, so that all magnetic fields encountered may be mapped. Either relative or absolute vertical intensity may be determined.

Careful calibration of the Superdip at least once each field season, and occasional comparison of the field results with magnetometer data can insure an accuracy high enough for ordinary magnetic survey work in iron ore prospecting.

The conventional method of correcting Superdip readings for temperature changes is considered inadequate; therefore it is believed advisable to make temperature corrections in accordance with the theory presented in this paper.

Acknowledgments

The author wishes to express his appreciation to all those who assisted in the experiments described. In particular, he is indebted to members of the Geological Dept. of the Cleveland-Cliffs Iron Co. of Ishpeming, Mich., especially to E. L. Derby, Chief Geologist, who arranged for permission to publish the results. He also wishes to express his thanks to Lloyal O. Bacon, Assistant Professor of Geophysics at the Michigan College of Mining and Technology, and to Burton H. Boyum, Assistant Chief Geologist of the Cleveland-Cliffs Iron Co., for many helpful suggestions. Professor Theodore Pearce, of the Department of Public Relations at the Michigan College of Mining and Technology, suggested improvements in expression and form. Professor Paul R. Hinzmann, Carl J. Huss, and Miss Jean Feldscher, all of the Physics Dept. at the College, were very helpful in the preparation of the manuscript.

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New Device Eliminates Blasting in Coal

A non-explosive device developed by duPont utilizes the high pressure of a gas generated inside a steel tube which is inserted in a hole drilled in a coal seam to break down the face of coal. Chemical reaction is started by an electric current which produces heat to initiate the action. The same heat destroys the starter wire as soon as electric current is no longer needed.

The tube containing the chemical is closed at the outer end by a plug with electrical connections, and at the other with a disk that is ruptured by the compressed gases formed. When the gas has been liberated in sufficient quantities to create a desired pressure the disk breaks and the released gas breaks down the coal face. The new device is called a Chemechol.

Ray C. Newhouse Dies

Ray C. Newhouse, who retired in 1945 as manager and chief engineer of Allis-Chalmers basic industries dept., died Aug. 27 at his home in Milwaukee at the age of 76.

Newhouse, who was retained by Allis-Chalmers in a consulting capacity after his retirement, gained world fame as an engineer, inventor and designer of some of the world's largest cement and mining machinery.

He specialized in crushing and mining engineering, designing many types of crushers, mills, kilns, coolers and dryers. He held nearly 100 United States patents and many foreign patents on machinery and methods for the manufacture of Portland cement.

Boyd Resigns Bureau; Takes Executive Post With Kennecott

Dr. James Boyd has resigned his post as Director of the U. S. Bureau of Mines and will leave on Oct. 16. Simultaneous with this announcement, Charles R. Cox, president of Kennecott Copper Corp., announced that Dr. Boyd is joining Kennecott's executive staff.

Born in Western Australia, Dr. Boyd received his early education in Australian and English schools. He completed his education in the United States, receiving degrees from California Institute of Technology and the Colorado School of Mines.

A reserve officer in the Corps of Engineers, Dr. Boyd was placed on active duty in 1941 in the office of the Under Secretary of War. In 1942, he was appointed to the requirements committee of War Production Board. Later he became assistant to Gen. Lucius D. Clay, and when General Clay established his command in Europe, Dr. Boyd, by then a full Colonel, assumed the position of Director of Industry.

Upon his return to civilian life in 1946, Dr. Boyd became dean of faculty at the Colorado School of Mines, relinquishing that post in March 1947 to become Assistant to the Secretary of the Interior. A few months later he was appointed Director of the U. S. Bureau of Mines.

New Sulphur Deposit On Mississippi Delta

Discovery of a large new deposit of sulphur which is expected to be a major factor in solving the current world shortage of this essential mineral was announced by Freeport Sulphur Co.

To develop the deposit, located at the mouth of the Mississippi River, Freeport will build a $10 to $15 million mining plant having a production goal of 500,000 long tons of sulphur a year according to John Hay Whitney, chairman of the board of directors, and Langbourne M. Williams, Jr., president.

The mine, the largest single sulphur development anywhere in the world in nearly 20 years, is expected to be ready for operation in 1953, the officials announced. Garden Island Bay is in the marshes of the lower Mississippi River delta 100 miles southeast of New Orleans. The deposit is native sulphur, or brimstone, which is the cheapest and purest of the various forms of the element. The sulphur occurs in a typical salt dome formation.

The dome was discovered by the Texas Co. in exploring for oil, which is being produced from the flanks of the formation. Freeport obtained the sulphur rights early in 1951 and under its lease will pay the Texas Co. 50 pct of the profits derived from the operation.

Mining News Fronts

• Climax Uranium and Minerals Engineering are said to be concluding contracts of major importance with Stearns-Roger Construction Co. Reports are that Climax will build a new addition to its plant at Grand Junction, Colo., the old Holly Sugar factory, and a new building is being planned for Minerals Engineering. Deliveries of steel are expected in January or February.

• Calumet & Hecla Consolidated Copper Co., Calumet, Mich., has entered into a $568,193 contract to explore for copper on numerous properties in Houghton and Keweenaw Counties. The Government will contribute 50 pct of the cost. This contract is one of the largest to date in the search for key metals and nonmetallic minerals.

• The Marmoraton Co., subsidiary of Bethlehem Steel, is developing an iron ore deposit at Marmora, Ont., 30 miles north of Trenton, and 100 miles east of Toronto. Mining operations are expected to employ approximately 225 men. Stripping the 150-ft thick limestone capping is expected to take approximately 2 years.

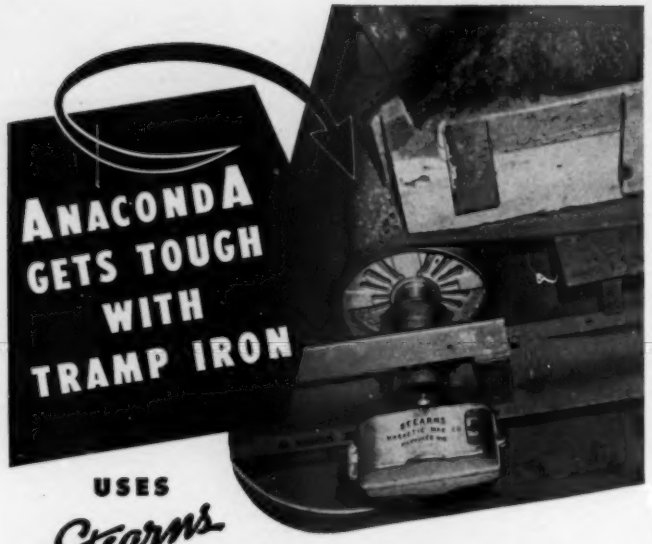
• Eldorado Mining & Refining Ltd. is embarking on a multimillion dollar construction program designed to get a new uranium discovery at Beaverlodge Lake in the Lake Athabaska area into production at the rate of 500 tons daily by early 1953. The mill will be designed to expand up to 2000 tons per day. A 5-compartment shaft is being sunk to an initial depth of 1150 ft.

In addition to the Eldorado operations, numerous other explorations in the Lake Athabaska area, which lies athwart the Alberta and Saskatchewan borders near the town of Goldfields, are disclosing promising prospects. A major new mining camp is said to be in the making.

• A second electric furnace will be installed in the Monsanto Chemical Co., Soda Springs, Idaho, plant to produce phosphorus after the first goes into operation late in 1952. The second furnace will double the capacity of the plant which will employ approximately 100 persons. The first furnace alone will produce about 9 pct of the total U. S. phosphorus output.

• The Venezuelan government is considering the construction of a small steelworks to utilize the recently available domestic iron ores. This new plant, designed by American engineers, which may use natural gas to reduce the ore and to generate electricity for electric steelmaking furnaces, is being considered by the Venezuelan government near San Felix, close to the iron mines.

• Consolidation Coal Co. began work on a new preparation plant at Fairmont, W. Va., that will produce approximately 8500 tons of washed coal daily for the company's Williams mine. Two washing circuits, including one for fine sizes, will be installed. A variety of sizes up to 5-in. will be produced. Fairmont Machinery Co. is constructing the plant which is expected to be in operation late next year.



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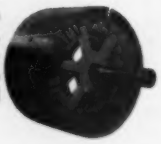

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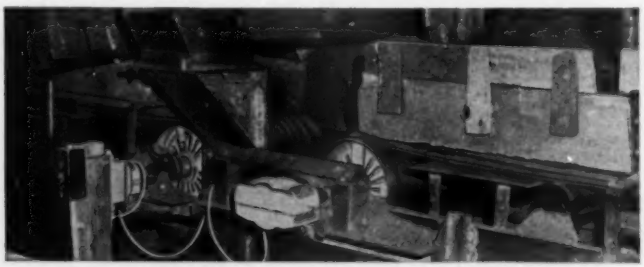

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Niobium or Columbium

The Commission on Inorganic Nomenclature of the International Union of Chemistry recently came a cropper in a run-in with Electro Metallurgical Div. of Union Carbide and Carbon Corp. over the decision of the former organization to call columbium, niobium. All this occurred in the pages of that worthwhile publication *Mineral Information Service* of the California Dept. of Mines. This sits badly with Electro Met which has established in the stainless steel industry its product names—ferro-columbium and ferro-tantalum-columbium. Military requirements are reportedly greater than computed occurrence of the metal in the earth's crust.

Diatomite Factory Is Being Enlarged

Critical shortages in many types of diatomite filter aids and fillers are expected to be eased by the end of this year when expanded production facilities are completed at Johns-Manville Corp.'s Lompoc, Calif., plant and mine, according to Arthur Elsenblast, general manager of the Celite Div. Planned expansion from the Lompoc deposit, believed to be the largest in the world, will increase output by 40 pct.

Among the facilities added at Lompoc is a calcining system with a large rotary kiln 10-ft in diameter and 110-ft long. The diatomite will be calcined with and without chemicals in this kiln at temperatures of 1800° to 2000°F. The calcination removes all organic matter and free and combined water from the raw diatomite and changes the crystalline form as well as the size of the particles.

The fastest growing use for diatomite and a complete new field is for clarification in the production of antibiotics such as the sulfas, penicillin, terramycin and aureomycin.

New Electroplating Method Conserves Metals

Westinghouse Electric Corp. has developed a new process of electroplating which conserves nickel in such non-essential uses as automobile trim and other bright work. A layer of copper about 0.001 in. thick is electroplated to the steel base. Over this is put a layer of nickel about one half as thick. Then an extremely fine film of chrome is applied.

The key feature of the new plating system is an electrical "backstroke" that alternately applies metal then takes some of it away by reversing the current. In ordinary methods of electroplating a continuous flow of direct current is sent through the electrolytic bath until a coating of the desired thickness is obtained. Surfaces are lumpy when examined under a microscope and have to be polished.

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aime NEWS

Southern California Section Announces Fall Meeting Program

THE following is the program to date for the fall meeting of the Southern California Section, AIME. The meeting will take place on Thursday, Oct. 25, 1951 at the Elks Club, 607 Parkview, Los Angeles.

OCTOBER 25, 1951

Registration

9:00 am to 4:00 pm

Morning Technical Sessions

9:30 am, El Venado Room

David B. Scott, Harrison Evans, Co-Chairmen

Opening Remarks: A. B. Cummins, national chairman, Industrial Minerals Div.; director, research dept., Johns-Manville Co., N. J.

Recovery of Alkaline Salts from Searles Lake By The West End Process: J. V. Wiseman and L. A. Blackmun, research chemist and technical director, respectively, West End Chemical Co.

Uranium Deposit, Grants, N. Mex.: T. O. Evans, system mining engineer, Atchison, Topeka & Santa Fe Railway Co.

Research Activities at the Boulder City Station, U. S. Bureau of Mines: C. T. Baroch, engineer-in-charge, Lead-Zinc Section.

Afternoon Technical Sessions

2:00 pm, El Venado Room

Nicholas D'Arcy, Conrad Thomas, Co-Chairmen

California Steatite, Resources and Characteristics: R. S. Lamar, Sierra Talc & Clay Co., and L. A. Wright and T. E. Gay, California Div. of Mines.

Some Applications of FluoSolids: T. B. Counselman, manager, FluoSolids Sales, Dorr Co.

The Dorr Way, color film: Dorr Co.

To be announced.*

Business Meeting

4:00 pm, El Venado Room

R. M. Stewart, Chairman, Mining Branch, Southern California Section, presiding

Reports of officers.

Report of nominating committee.

Miscellaneous business.

* A program will be available at the registration desk. Abstracts of the papers and biographical sketches will be included. Preprints will also be available at the time of registration.

Mexico City Meeting Technical Program

Mining, Geology, and Geophysics Div.

TUESDAY, OCTOBER 30

10 am
Joint Mining-Geology Session

Geology and Mineral Deposits of Mexico: T. P. Clendenin, chief geologist, Mexican Mining Dept., American Smelting & Refining Co.

Mexico's Thousands of Independent Miners—the Gambusinos: R. M. Atwater, Jr., consulting engineer, and G. W. Jarman, Jr., president, Separations Engineering Corp.

Antimony Deposits of the San José Mine: J. C. Archibald, Jr., general superintendent, Cia. Minera y Refinadora Mexicana, S. A.

Relation of Orebodies to Dikes in the Pachuca-Real del Monte District, State of Hidalgo: A. R. Geyne, geologist, Cia. de Real del Monte y Pachuca and Ivan F. Wilson, geologist, U. S. Geological Survey.

4 pm
Mining Session

San Antonio Mine, Santa Eulalia, Chihuahua: C. M. Syner, general superintendent, and W. P. Hewitt, geologist, Santa Eulalia Unit, AS&R Co.

Application of Jumbo Mountings to Drilling in Stopes in Veins of Medium Width: Vicente Cisneros, general superintendent, Esmeralda Mine, Eagle-Picher de Mexico.

Water Problem of Leon Congreso Mine: Luis Villasenor, manager, Minas de Durango.

Mining Operations of the Braden Copper Co.: F. E. Turton, general manager, Braden Copper Co., Sewell, Chile.

WEDNESDAY, OCTOBER 31

10 am
Joint Geology Subdivision and Society of Economic Geologists Session

Uranium Deposits of Mexico.

General Policy for Raw Materials for Atomic Energy: W. J. Bennett, president and general manager, Eldorado Mining & Refining Ltd.

Uranium Deposits of Canada: B. S. W. Buffam.

The Search for Uranium: Jesse C. Johnson, director, Raw Materials, Atomic Energy Commission.

Uranium Exploration: Phillip L. Merritt, assistant director, Div. of Raw Materials, U. S. AEC.

4 pm
Geology Session

Correlation of the Sedimentary Section at Cananea with the Section in Southern Arizona: J. Ruben Velasco, chief geologist, and Roland B. Mulchay, geologist, Cananea Consolidated Copper Co.

Structure of the Guadalupe Orebody, Tayoltita, Durango: Paul C. Henshaw, geologist, San Luis Mining Co.

Geology of La Luz Mines Ltd., Siuna, Nicaragua: G. A. Nelson and C. L. Spencer, La Luz Mines Ltd.

Mineralogy of the Guanajuato Gold-Silver Veins.

4 pm
Geophysics Session

Miniature Seismic Refraction Mapping in Mining and Civil Engineering: R. Burton Rose, Allied Geophysics.

Ground Water Problems in Mexico: Luis Floris Cavarrubias.

Aeromagnetics: Homer Jensen, chief, magnetometer div., Aero Service Corp.

Minerals Beneficiation Div.

TUESDAY, OCTOBER 30

8 am MBD Rancheros Breakfast
10 am Mexican Milling Operations Session

Lead-Copper Separation Processes at the Fresnillo Corp.: C. J. Veale, mill superintendent, Fresnillo Corp.

Application of Preflotation to Cyanidation Ores at Real del Monte y Pachuca: R. R. Bryan, general superintendent of mills, Real del Monte y Pachuca.

Effect of Zinc Deleading Operations on Lead-Zinc Selectivity at the Parral and Santa Barbara Units of the AS&R Co. C. L. Boeke and C. G. Gunther, respective mill superintendents, AS&R Co.

3 pm
Materials Handling Session

Comparison of Aerial Tramways vs Belt Conveyors for Ore Transportation. Selected papers and discussion.

WEDNESDAY, OCTOBER 31

10 am
Grinding and Classification Session

Development of the Use of Screened Ore for Fine Grinding at Lake Shore Mines: B. S. Crocker, mill superintendent, Lake Shore Mines.

Third Theory of Comminution: Fred C. Bond, Allis-Chalmers Mfg. Co.

Classification: H. W. Hitzrot, Dorr Co.

1 pm MBD Luncheon and Business Meeting
3 pm Informal Seminar on Milling, and Cleanup Session

Industrial Minerals Div.

TUESDAY, OCTOBER 30

4 pm

Perlite—the New Industrial Mineral: E. J. Mayhew, consulting geological engineer, Albuquerque, N. Mex.

Diatomite in Mexico: Victor Felix, general sales manager, Diatomex.

Nonmetallic Deposits of Mexico: Teodoro Flores, director, Universidad Nacional Autonoma de Mexico.

Sulphur Deposits in San Luis Potosi State: Jenaro G. Reyna, Universidad Nacional Autonoma de Mexico.

Mineral Industry Education Div.

Tentative Program—Dates Not Set

Point Four Program: Edward Steidle, dean, School of Mineral Industries, Pennsylvania State College.

Mining Curricula in the United States.

Mining Engineering Curricula at the University of Mexico.

Metallurgical Engineering Curricula in the United States: D. S. Eppelsheimer, professor of metallurgical engineering, Missouri School of Mines and Metallurgy.

Metallurgical Engineering Curriculum at the University of Mexico.

Geological Engineering Curricula in the United States: Philip J. Shenon, chairman, div. of mineral engineering, University of Utah.

Geological Engineering Curriculum at the University of Mexico.

Petroleum Engineering Curricula in the United States: H. H. Power, chairman, petroleum engineering dept., University of Texas.

Petroleum Engineering Curriculum at the University of Mexico.

Registrations Received to Date For AIME Mexico City October Meeting

The following is a list of people who have registered and signified their intention to attending the Mexico City meeting.

C. E. Golson, Paul V. Svendsen, Clarence F. Zeuch, Robert Lindley Ziegfeld,* Harley A. Coy,* Lionel E. Booth,* W. G. Rowillard,* R. E. O'Brien,* Vincent D. Perry,* J. P. Bleeg, G. N. Wilson, John C. Lokken,* J. R. Atkinson, Henry C. Morris,* Frank J. Downey,* J. F. Myers,* John I. Clemens,* B. Delany,* S. J. Swainson,* W. Martin Fitzsimmons, G. W. Jarman, Jr.,* F. E. Wood,* Harlowe Hardinge,* E. H. Robie,* W. M. Peirce,* Richard H. Allen,* Henry W. Hitzrot,* J. Delano Hitch, Jr.,* A. C. Hall,* R. J. Mellen,* W. A. Conley,* William Clemens,* John T. Lonsdale, Norman Weiss, C. J. O'Connell, James Fisher, Harry K. Beggs, Ing. Jose Carrasco, T. B. Ford,* G. O. Wilson, S. T. Harrison, H. E. Bolton, E. R. Ramsey,* Alan Kissock,* H. F. Hurley, W. E. Mahin, A. P. Thompson, Joseph T. Singewald, Jr., Bruce W. Gonser, C. F. Thompson, J. P. Bonardi, Albert J. Phillips.

J. G. Hall, Harold B. Spencer, Alex Nielson and group, J. J. de la Fuente, Stanley M. Moos, William B. Stephenson and group, W. Todd, Theodore Marvin, K. A. De Longe, William A. Mueller, J. V. Reynolds, Willard Berry, J. L. Gillson,* Sherwin Kelly,* George H. Deike,* J. T. Ryan, Jr.,* C. M. Donahue,* G. S. Stringfellow,* Nels P. Peterson,* Clinton Bernard,* Oliver C. Ralston,* J. R. Cudworth (2 couples), Alice R. Warren (4 people), George M. Fowler,* Baltazar Martinez,* Philip J. Shenon, Oliver Bowles,* A. John Bittson, Herbert H. Hanley,* C. R. Ince, W. I. McInerney,* C. F. Thompson, O. H. Johnson, J. D. Price, J. Walter Snavely, O. E. Jack, O. C. Schmedeman, Arch A. Sproul,* Cecil A. Fitch, Sr.,* Bert Crips,* J. G. Duff, R. L. Jourdan, J. Dickerson Martin,* Ira B. Joralemon, Wm. D. Blankenship,* Franklin E. Johnson, W. H. Leverett, Bent. W. Vallat, Arthur J. Blair,* J. C. Neemes, A. G. Zima, John V. Beall.*

Walter H. Zwick,* A. T. Ward, J. H. Pollard,* Frank Ayer,* E. F. Salisbury,* Richard Vail, Charles S. Smith, Fredrik Mogensen, Louis Moyd, G. Gutzeit, J. F. Mitchell-Roberts, H. T. Blackwood,* Edwain H. Crabtree, Jr.,* Elmer H. Isern,* Hugh M. Craigie & 2 ladies, John D. Grothe, John W. Foreman, C. L. Spencer,* Graham Nelson,* Ross Field,* W. T. Bishop, Olaf P. Jenkins, William M. Zilbersher, C. J. Nelson, Dr. Seeber,* J. Wilber Van Evera,* Harry L. Miller,* J. V. Reynolds, David J. Barsa, Dan Walker, Maj. Charles S. Merriam, G. W. Irvin, L. J. Slessinger, M. E. Hurst, Hans Lundberg,* S. S. Clarke,* J. P. Chilcote, F. Polson and friend, C. L. Sollenberger, Will Mitchell, Jr., Fred Bond and son,* Francis Cameron and daughter.*

* Indicates Mr. and Mrs., or party.

EMC Holds Manpower Convocation

A convocation of engineers, educators, and industrialists was held to discuss what must be done to maintain and increase the national supply of engineers needed for civilian economy and the Armed Services. The meeting in Stephen Foster Memorial Hall, University of Pittsburgh, was sponsored by the Engineering Manpower Commission of Engineers Joint Council, and arranged by the Engineers' Society of Western Pennsylvania with its president, G. A. Shoemaker, as chairman.

Representation from Pittsburgh included educators from both secondary schools and colleges, as well as representatives of industry and the engineering profession. Delegations of engineers from other areas throughout the country were also present to learn of the programs developed by EMC to combat the problems created by the critical shortage of engineers.

Annual Award Inaugurated By MIED For Advancement in Education

The AIME has established an award to be "given for distinguished contributions to the advancement of mineral industry education." This award, it is planned, will be presented annually in recognition to men devoting their careers to the all-important tasks of teaching, or to those who have made other contributions in the advancement of education in the various phases of the mineral industry.

To inaugurate and perpetuate this award, a committee has been named to raise necessary funds. Interested members, their companies, and friends of AIME are invited to contribute to the fund, the income from which will provide the award. Contributions should be made to the AIME, Mineral Industry Education Award, and sent to Institute headquarters.

How About You?

If either your address or position change you owe it to yourself and friends to let AIME headquarters know as soon as possible, a month before the change is made if you can give your future address accurately. Please follow these suggestions: (1) Give your name and the address to which publications and correspondence should be sent. Mark this: "Publications address." (2) Give your name, title, or company position, and your address the way you want it to appear in the next Directory. Mark this: "Directory listing." (3) A short personal item for publication will be appreciated.

Send your advice, by postal card or letter, to: AIME, 29 W. 39 St., N. Y. 18.

Lost!

The following are members of AIME who have lost contact with Institute headquarters and consequently their addresses are obsolete. If anyone should know their whereabouts kindly contact the headquarters office in New York.

William F. Allinder
Leland R. Croft
George De Mohrenschildt
Ray J. Haffner
Alexander R. Kingaard
Alexander Labounsky
Walter Arnold Rukeyser
Pisoot Sudasna

Rocky Mountain Members:

Oswald F. Benwell
N. E. Franklin
Henry D. Lindsley
R. A. Loomis
Gilbert McClurg
A. H. Pogson
George L. Ramsey
W. E. Richardson
Harry L. Rodgers

AIME Petroleum Branch Moves

AIME Petroleum Branch offices in Dallas have been moved from the Continental Bldg. to Suite 408, Trinity Universal Bldg., Dallas 1. The building is on the corner of Harwood St. and Ross Ave., where Joe B. Alford, executive secretary of the Branch, and Jess E. Adkins, editor of the JOURNAL OF PETROLEUM TECHNOLOGY, and their staff will be pleased to greet any AIME members, petroleum or not, who may care to call.

DeGolyer Elected Honorary Member

Dr. Everette Lee DeGolyer was elected an Honorary Member of AIME at the meeting of the Board of Directors on Sept. 12, 1951. Election was made by written ballot on the recommendation of the Committee on Honorary Memberships, of which Clyde Williams is chairman.

Dr. DeGolyer is a partner in the company DeGolyer & MacNaughton, Dallas. A geologist and petroleum engineer, he was affiliated with Amerada Corp. from 1919 to 1932 as vice-president and general manager, president and general manager, and chairman of the board. He was also president of the Geophysical Research Corp., and in 1940 was the Distinguished Professor of Geology at the University of Texas.

Dr. DeGolyer was the 1940 Cyrus Fogg Brackett Lecturer, the 1941 Louis Clark Vanuxem Lecturer, and in 1939 received the Princeton University Distinguished Service Award, Texas Div., Mid Continent Oil & Gas Assn., for independent petroleum producers.

In 1942 Dr. DeGolyer was the recipient of the John Fritz Medal, the AIME Distinguished Achievement Award in 1942, and he also was awarded the Anthony F. Lucas Gold Medal. In 1927, he was president of the AIME.

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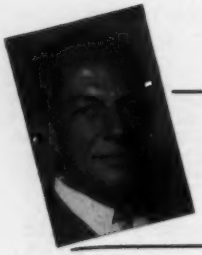


THE DRIFT OF THINGS

by Edward H. Robie

HELPING to plan for a big AIME meeting 2110 miles away, in Mexico City, while sitting on our tail in New York during a particularly muggy summer has its disconcerting moments. Normally, Fall Meetings are held in the States where long-established Local Sections can act as hosts, with considerable experience and financial resources to guide them and help them out. In the present case, there was no Local Section in Mexico when the idea of a meeting there was first broached. One was later formed, with about 50 members. It received $100 as a Local Section appropriation for 1951. With no money and only a handful of active members it was plain that the usual committees to take care of all phases of a meeting could not be set up. The services of an organization thoroughly familiar with handling conventions in Mexico were therefore enlisted. This organization contracted with the hotels to secure the number of rooms thought to be necessary, developed the social program, printed the prospectus for the meeting, and handled all correspondence. The local AIME committee worked closely with this organization, and we have every assurance from the Local Section officers that AIME members, their ladies and friends, will be well taken care of and that the costs are reasonable for the services performed. In fact, it appears that the meeting has been undersold; it appears likely that those who go to the Mexico City meeting at the end of October will return with a feeling that they would not have missed it for the world. It has already begun to click, and we are told that the Government and every one else will go out of their way to see that everybody has a superlative time if a sufficiently impressive number of our members attend.

Following several long-distance telephone calls, dozens of letters, and visits in New York from the Secretary of the Mexico Section, Bill Kane, and both the general manager and the president of Aguirre's Guest Tours, we believe that the success of the meeting is now assured. That is, if all 800 of you come—a figure on which we have sort of set our sights.

Mexico is a country that almost everybody has hoped or planned to visit at some time. For mining people and their ladies this is an exceptional opportunity to make dreams come true—weather conditions for the trip and while there should be ideal. There will be plenty of people you know, and social attractions and field trips that the mere tourist never has a chance to enjoy.

Saving the Taxpayers' Money

On p. 18 of a report of a press conference of the U. S. Atomic Energy Commission we read: "We just wanted to make the report a little shorter this time and save the taxpayers' money."

On p. 2: "*Question:* Morse, when we get through with the report, the other questions are for immediate release?" *Mr. Salisbury:* Yes, sir. So let's start now on the report. *Question:* Mr. Salisbury, before you do start, with reference to the time, 12:30 release, tomorrow, is that eastern daylight or eastern standard? *Mr. Salisbury:* Eastern daylight."

Now for even more vital information, let's skip over to p. 19, where they are talking about the dogs on Eniwetok Island used to test the effect of radioactive material on animals: *Question:* Mr. Dean, back again to the subject of breeders (the reference is to the experimental breeder reactor at Arco, Idaho), what about these dogs that you have on Eniwetok? Are they any special breed? Or just mongrels, or what not? *Chairman Dean:* Not to be confused with the breeder reactor. *Question:* You did refer in your report to breeding your own animals out there, and there has been some question as to what type of dogs, just ordinary dogs, or whether some of your scientists were going out of their way to breed something unusual. *Commissioner Pike:* I don't think you would have that impression if you had seen some of the dogs. *Question:* I did have in mind trying to get one of it is a good dog. Is a dog which has been heavily exposed to radiation known as a 'hot dog'?"

Writing Technical Papers

A. J. Murphy is president of the Institute of Metals (the British Society) this year, and in his presidential address he refers to the first committee job that he had with that institute—serving on its Publications Committee. He then refers to the work of this committee, and his remarks are pertinent also to the AIME and to our own Technical Publications Committee:

"Publications constitute by far the most important activity of the Institute in terms of financial commitment and allocation of staff. . . . Therefore, this side of our affairs has to be watched carefully. . . . There has been complete unanimity on the necessity of maintaining our high standards of presentation and also on the desirability of publishing all papers submitted which are judged by the Publications Committee to be acceptable on grounds of merit and interest. The Publications Committee, anxious to follow these principles and at the same time mindful of the need for economy, has to be on guard against extravagance in such things as photographs, which are costly to reproduce. . . . When referees find the text to be unduly long, it is often rather difficult to suggest exactly where excision or abridgment might be achieved. With the best will in the world, moreover, an author not uncommonly is hard put to it to reduce an already written account by, say, 20 pct. . . . Authors should therefore make a serious effort to effect the greatest condensation consistent with easy reading before submitting their manuscripts. There are few papers which would not actually be improved in clarity by an hour or two of the author's time being devoted to the removal of superfluous words and phrases.

"There are two other causes of unnecessary length in papers. . . . One results from an author failing to realize that a document suitable as a report to a research committee may not be in the best form for a paper intended for presentation (oral) to the Institute. . . . The second cause of avoidable bulk is the inclination of an author to present his paper as a chronological account of his investigations. . . .

"If authors would bear these points in mind and make a special effort to submit a manuscript shorn of all unnecessary trimmings, they would have the satisfaction not only of having produced a more easily assimilable account, but also of knowing that they had made a useful contribution towards keeping down the cost of the Institute's publications."

Personals

Ruperto G. Aguilar has been promoted to unit superintendent, Minera Guadalupe, S. A., Guerrero, Mexico.

Baird E. Anderson, American Smelting & Refining Co., has been transferred from the Tacoma plant to the western engineering dept., Garfield, Utah.

Kellog Burham will take charge of the operation of Cia Fundidora, La Concha, S. A. as managing director.

Henry E. Brown, formerly with Patino Mines & Enterprises, Inc., Catavi, Bolivia, is now with the Bolivian Tin & Tungsten Mines Corp., Huanuni, Bolivia.

Antonio M. Boquer has joined the staff of the Surigao Consolidated Mining Co., Surigao, Mindanao, Philippines.

James H. Brockman has become associated with the engineering dept. of the Chino div., Kennecott Copper Corp., Santa Rita, N. Mex., as a junior engineer trainee.

A. A. Bakewell, formerly assistant chief engineer at McGill with the Kennecott Copper Co., has been promoted to mine project engineer.

Vearle W. Balderson is with the Federal Power Commission, Albuquerque, N. Mex.

James H. Courtright has joined the Nigerian Lead Zinc Mining Co., Ltd., Nigeria, West Africa.

Ferdinand E. E. Dierkens has joined Materiels & Materiaux de Construction S. A., Brussels, as manager.

E. C. De Moss has resigned from the Bradley Mining Co. and is now located at Emmet, Idaho.

ROBERT CLARKSON

Robert Clarkson has resigned his position with the Bradley Mining Co. He will be engaged in production management of the associated firms of the Clarkson Co. and Equipment Engineers.

Lucien Eaton, Jr. is employed by the Western-Knapp Engineering Co., Hibbing, Mich. He was formerly with the Aluminum Co. of America.

G. R. Fitterer has been appointed dean of the schools of engineering and mines, University of Pittsburgh. He had been professor and head of the metallurgical engineering dept.

Jack D. Frank is now assistant mining engineer for the Copper King mine, Golden Century, Inc., Carlin, Nev.

Willard P. Fuller, Jr. has joined the Original Sixteen to One Mine, Alleghany, Calif., as geologist.

Clarence A. Fredell has resigned as assistant general superintendent in charge of mining operations for San Francisco Mines of Mexico, Ltd., San Francisco del Oro, Chihuahua, Mexico. He has accepted a position with the ECA as a mining engineer in the Materials Development Div., Washington, D. C.

WILLIAM GRUENERWALD

William Gruenerwald has opened his offices as consulting geologist in the Pure Oil Bldg., Chicago. For the past two years he had been associated with the Paul Weir Co., Chicago.

Harold H. Haman, Jr. is now with the Eagle Pitcher Mining & Smelting Co., Galena, Ill.

John F. Haynes has been transferred from the Santa Barbara unit of the Compania Minera Asarco, S. A., to mine foreman of the Plomosas unit of the Compania Minera Nacional, S. C., Chihuahua, Mexico.

Walter B. Hollow, North American Car Corp., Chicago, has been transferred to Dallas.

John B. Hazle has been promoted to the post of general works manager of Interlake Iron Corp. and will be located in Cleveland. Mr. Hazle had been general superintendent of the Toledo plant.

MAYER G. HANSEN

Mayer G. Hansen, geologist and mining engineer, E. J. Longyear Co., Minneapolis, has been transferred from the sales div. to the mining div.

L. R. Louis has been appointed sales manager with headquarters at Minneapolis.

Robert H. Holgers is now with the Montreal Mining Co., Montreal, Wis.

Earl E. Hunner has retired from the M. A. Hanna Co. He has been with the firm for 34 years. Since 1946 he has been executive consultant.

Ray L. Hampton was named vice-president in charge of sales by Mosebach Electric & Supply, Pittsburgh. He was formerly sales manager. Before joining Mosebach he was manager of Controller Block & Supply Co., Kermit, W. Va.

Willard H. Hawley is now employed as a metallurgist at the Navy Dept., Bureau of Ships, Washington, D. C.

Philip J. Johnson is now mine foreman for U. S. Gypsum Co. at Oakfield, N. Y. He was formerly coal mining engineer for Rock Island Improvement, Peoria, Ill.

James H. Jacobs is now associated with Union Carbide & Carbon Research Laboratories, Inc., Niagara Falls, N. Y. He resigned from the U. S. Bureau of Mines, Manganese Research.

S. T. Keel has been named domestic sales manager of the phosphate div., International Minerals & Chemical Corp. He had been manager of the southern district of the phosphate sales dept.

James W. Kinnear, Jr. is assistant to vice-president, manufacturing, U. S. Steel Co., Pittsburgh. He had been associated with Firth Sterling Steel & Carbide Co., McKeesport, Pa.

Marvin Kay has been named vice-president and general manager of Climax Uranium Co.

J. JOSEPH KELLEHER

J. Joseph Kelleher was appointed an assistant director of sales for Hercules Powder Co., explosives dept. He will also assist the director on general sales assignments.

John P. Lowe has returned as general superintendent for Metal Producers, Inc., Horn Silver mine, Milford, Utah. He had been with Southwestern Engineering Co., Los Angeles as field engineer for 1½ years. Prior to this he was with Metal Producers, Inc.

Herbert H. Lauer, consulting industrial engineer, has moved from Philadelphia to Orlando, Fla.

P. L. Lockridge, formerly general superintendent of the Torreon smelter, American Metal Co., has become superintendent of the smelter at Socavon, Queretaro, Mexico for Compania Minera Esmeralda, S. A.

S. D. Michaelson, formerly chief engineer of coal mines for Tennessee Coal, Iron & Railroad Co., Birmingham, has been appointed to the newly created position of chief engineer for raw materials.

James B. McKay is now sales engineer, FluoSolids sales div., Dorr Co., Stamford, Conn. He had been mill superintendent, Campbell Red Lake mine, Balmertown, Ont.

Julius H. Moor is now employed by the Alaska Road Commission, Valdez, Alaska, as an engineering aid.

Thomas W. Mitcham was recently awarded Ph.D. degree in geology and has returned to the American Smelting & Refining Co. He has been assigned to general exploration in the southwest div., Tucson.

Robert A. Muhs is now employed by the Day Mines, Inc., Wallace, Idaho.

William B. MacPhee is with Capitana Gold Mines Co., Lima.

John Thomas Moran is now employed by the Freeman Mining Corp. as assistant to the chief engineer at the Crown mine at Farmersville, Ill.

Hardinge HAS *it!*

• **CONICAL MILLS**

The Hardinge Conical Ball (or Pebble) Mill is unequalled in efficiency. Natural size segregation of grinding media, from feed to discharge. Bulletin 17-B-2 for dry grinding; Bulletin AH-389-3 for wet grinding.

• **TRICONE MILLS**

Same ball segregation effect as obtained in the Conical Mill, plus additional grinding volume. Ideal for large capacity operations. Bulletin AH-414-2.

• **HEAVY-MEDIA SEPARATORS**

On the Iron Range, actual tests have proven the Hardinge Heavy Media Separator the most efficient of all types of separators. Low maintenance requirements. Bulletin 39-B-2.

• **COUNTER-CURRENT CLASSIFIERS**

For classifying, sizing or counter-current washing. A slowly revolving drum without internal moving parts. Will start under full load. Bulletin 39-B-2.

• **"AUTO-RAISE" THICKENERS**

"Auto-Raise" driving mechanism lifts scrapers above all obstructions and overloads—eliminates breakage. Spiral scraper cleans tank bottom in one revolution. Bulletin 31-D-2.

• **CONSTANT-WEIGHT FEEDERS**

Measure by weight, not volume. Eliminate variations due to change in specific gravity, bin segregation or size of material. Bulletin 33-D-2.

• **"RUGGLES-COLES" ROTARY DRYERS**

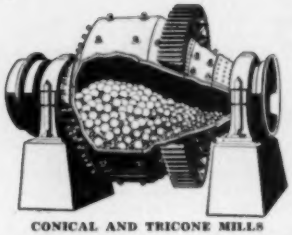
Double and single-shell rotary dryers in seven distinct types—designed for direct, indirect and steam heat. Rotary kilns for continuous calcining or roasting. Rotary coolers and vertical shaft kilns. Bulletin 16-D-2.

• **CYLINDRICAL MILLS**

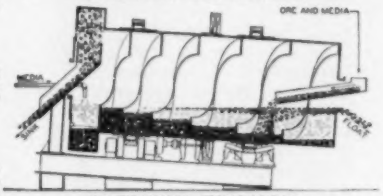
Hardinge Cylindrical Ball (or Pebble) Mills have demountable trunnions, and convex heads to reduce head liner wear and increase mixing action. Supplied with or without grates, as required. Bulletin AH-389-3.

• **ROD MILLS**

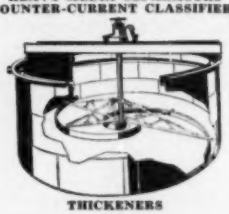
Ideal for producing minimum oversize in open circuit grinding. Grind either wet or dry. Conical Heads reduce friction, prevent congestion of charge at the ends, and align the rods. Bulletin 25-C-2.



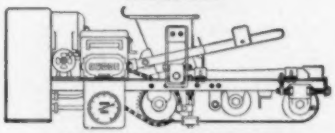
CONICAL AND TRICONE MILLS



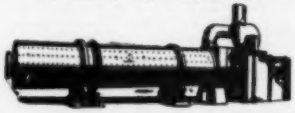
HEAVY-MEDIA SEPARATORS
COUNTER-CURRENT CLASSIFIERS



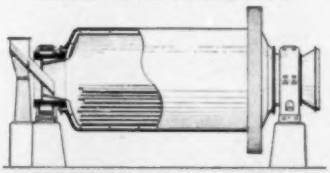
THICKENERS



CONSTANT-WEIGHT FEEDERS



RUGGLES-COLES DRYERS, KILNS



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George C. McMillen, Freeport Sulphur Co., has been transferred to Port Sulphur, La. as assistant general superintendent. He was previously located at Freeport, Texas.

Frank Marold is now with the Ore & Chemical Corp., New York.

Earl H. Miller has become assistant resident manager, U. S. Potash Co., Carlsbad, N. Mex.

Archie J. McDonell has resigned from the milling staff of Bunker Hill & Sullivan Mining & Concentrating Co., Kellogg, Idaho, to accept the position of mill superintendent with Vermont Copper Co., Inc., South Strafford, Vt.

William J. McPherson has joined the Calvan Consolidated Oil & Gas Co., Ltd., Calgary, Alberta, Canada.

William A. Newman, formerly in charge of hydraulic mining operations for Pato Consolidated Gold Dredging Ltd., Colombia, is now technical director for Aurifera Asturiana, S. A.

W. C. Newberg has been named president of the Chrysler Corp.'s Dodge Div. Mr. Newberg has been a vice-president of the div.

Malcolm F. Parkman is now a research metallurgist for Combined Metals Reduction Co., Stockton, Utah.

ROBERT L. SMITH

Robert Langland Smith, formerly with U. S. Steel Co., mining engineering dept., has been recalled to active duty with the Army Corps of Engineers, as a First Lieutenant.

Simon A. Prussin is now with Austenal Laboratories, Inc., New York.

George P. Powe has resigned as assistant resident engineer and assistant supervisor of mines for Northwestern Improvement Co., Roslyn, Wash. He will go into private business at Cascade, Mont.

Neil Plummer has been promoted from general mill foreman at the Magna mill, Kennecott Copper Co., to metallurgical engineer, Garfield mill, Utah.

W. L. Roller has been appointed vice-president, H. J. Daniels & Co., Inc., Hazleton, Pa.

Kenneth Rudd was elected treasurer of Link-Belt Speeder Corp., Cedar Rapids, Iowa.

Heath Steele, vice-president, American Metal Co., Ltd., and president of the Mexican subsidiary, had recently visited the Penoles properties in Mexico.

Edward P. Scallon has joined the M. A. Hanna Co., St. Paul as consulting mining engineer. He had been assistant to the president, Butler Bros., St. Paul.

Stuart St. Clair has left on a professional trip to Europe and Asia. He plans to return to the states in December.

William A. Spence has been appointed general manager, Ohio Hoist & Mfg. Co., Cleveland.

J. L. Singleton, vice-president in charge of the general machinery div. and **R. S. Stevenson,** vice-president in charge of the tractor div., have been elected to the board of directors, Allis-Chalmers Mfg. Co.

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GEOLOGICAL INVESTIGATIONS

Robert Duane Saltsman has joined the Buckeye Coal Co., Namacolin, Pa., as assistant preparation engineer.

Frank J. Smith, vice-president, Oglebay, Norton & Co., has been awarded the honorary degree of Doctor of Engineering by the Michigan College of Mining and Technology. He is also in charge of the taconite development of Reserve Mining Co. on the eastern Mesabi.

W. Cordes Snyder, Jr., has been elected president and chief executive officer of Blaw-Knox Co. He previously was a vice-president of the company in charge of its Lewis foundry & machine div. More recently he was vice-president of the Koppers Co. and manager of the metallurgical dept.

Charles E. Tonry has resigned from Southwestern Engineering Co. to accept a staff position with the U. S. Bureau of Mines at the oil shale demonstration plant, Rifle, Colo.

Robert E. Tally, Jr., is now assistant manager, Colorado Raw Materials, Grand Junction, Colo.

Robert W. Van Evera has joined the Reynolds Jamaica Mines, Ltd., Jamaica, B. W. I.

J. Wilbur Van Evera has been at the Blair Limestone div., Jones & Laughlin Steel Corp., as superintendent in charge of production of both the Blair and Millville quarries since April 1950. He has the specific assignment of changing over the Blair quarry to truck haulage.

E. C. Weichel, Jr. has joined the Humphreys Gold Corp., Jacksonville, Fla., as assistant to the vice-president. He resigned from the Davison Chemical Corp., Bartow, Fla.

Harold Worcester, formerly assistant general manager, Golden Cycle Corp., Cripple Creek, Colo., has accepted the position of executive vice-president of the King Lease Inc., Ouray, Colo.

Harry L. Washburn is now process engineer, research and development div., Pittsburgh Consolidation Coal Co., Library, Pa.

Robert F. Winkle has returned to Phoenix, Ariz., from Chuquicamata, Chile, where he was employed by the Chile Exploration Co.

R. T. Whitzel, Aluminum Co. of America, has been transferred from the Massena, N. Y. office to Pittsburgh.

Reginald R. Whitlock has joined the Western Precipitation Corp., Los Angeles.

Clarence Zener has been appointed an associate director of the Westinghouse Research Laboratories, Pittsburgh.

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Obituaries

Chester A. Fulton (Member 1907), a former president of AIME, died on Aug. 16, 1951. Mr. Fulton was born in Brooklyn, N. Y. on Dec. 18, 1883 and graduated with the degree of engineer of mines in 1906. After graduation he was employed by the Standard Smelting Co., Rapid City, S. D. as assayer and chemist. He then went to Mexico and joined the Peregrina Mining & Milling Co. working

CHESTER A. FULTON

in various capacities from shift boss to mine superintendent. In 1914 Mr. Fulton went to Venezuela as superintendent of the Lo Increible mine. He then spent two years in Cuba working on copper mines and in 1918 was manager of the Davison Sulphur Co., Cienfuegos, Cuba. Returning to the United States, he was consulting engineer for the Davison Chemical Corp., Baltimore for seven years. In 1928 he became vice-president of the Southern Phosphate Corp., Baltimore. He was made president in 1932 but retired in 1945. Mr. Fulton served on several committees of the Institute and in 1944 was elected President. He also authored technical papers on the phosphate rock industry.

C. S. J. Trench (Member 1945), editor and publisher of *American Metal Market*, died on Aug. 20, 1951. Born in New York, he attended Ridley College School at St. Catherine's, Ont. After a brief period in banking he joined Stewart Trench & Co., jobbers in tin plate and metals. In 1901 he became associated with C. S. Trench & Co., established by his father. He succeeded his father as president in 1929 and also became president and publisher of the paper.

Seely Benedict Patterson

An Appreciation by B. J. Larpenteur

Seely B. Patterson, mining engineer, executive, banker, and public spirited citizen, passed from this world to his final rest on June 10, 1951. He had been a member of the Institute since 1912, with particular interest in the affairs of the Industrial Minerals Div.

He was born in Quinnimount, W. Va., in 1885, the son of the late Seely B. Patterson, iron master and superintendent of the Robesonia Iron Co. in Pennsylvania. He was a grandson of Henry A. Patterson, founder of the hardware firm of Patterson Bros. still operating on Park Row, New York City. He attended Phillipsburg Academy, Columbia University, and

SEELY B. PATTERSON

the Colorado School of Mines, where he received his E.M. degree in 1906. He was elected to Tau Beta Pi.

Mr. Patterson was employed by the Robesonia Iron Co., the Spanish American Iron Co., in Cuba, the Anaconda Copper Mining Co., and Calumet & Arizona Copper Co. He returned to the Spanish American Iron Co. as general manager and then became assistant general manager of Cuban operations for Bethlehem Steel Co. He served as a Major in the U. S. Army Engineer Corps during World War I. Then, after spending some time with Midvale Steel Co., he became associated with the Calcite Quarry Corp., at Lebanon, Pa., as general manager, in 1920. He served that company for 31 years, and had been their president since 1946.

He was active in civic affairs in the Lebanon community, particularly in the organization of disaster relief during the past world war. Seely is survived by his wife, Adelaide Tapley Patterson, also a brother and a sister.

A lover of sports, he participated, himself, in golf, swimming and fishing until shortly before his death. He liked travel and adventure, and photography was one of his hobbies. He and Mrs. Patterson had recently returned from an Alaskan trip and were making plans for a tour of Africa to celebrate their 30th wedding anniversary, when his last illness intervened. Of all of his many interests and activities, however, his principal hobbies centered around his wife and their hospitable home in West Myerstown, Pa.

Mr. Patterson was discerning in his friendships and was determined in his principles and aims. He was widely known, both within and outside of the mining profession, and his passing is mourned by a host of friends.

Carl Arthur Lemke (Member 1916) died on July 31 of a heart ailment. Born in Brooklyn, N. Y. in 1880, he graduated from the Colorado School of Mines in 1900. In 1906 he joined the American Zinc Extraction Co., Leadville, Colo. as mill foreman and superintendent. He remained with this firm for approximately six years and in 1912 became associated with the U. S. Smelting Refining & Mining Co. He was assistant superintendent in charge of concentrator and then became superintendent of the mill. Mr. Lemke moved to Midvale as superintendent of the smelter.

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Later he joined the Potash Co. of America but retired about 10 years ago because of ill health.

NECROLOGY

Date Elected	Name	Date of Death
1914	L. Douglass Anderson	Unknown
1923	J. P. Bickell	Aug. 22, 1951
1912	Holcombe J. Brown	Unknown
1945	Ernest T. Croker	Oct. 4, 1950
1945	Walter J. Crown	Mar. 17, 1951
1907	Chester A. Fulton	Aug. 16, 1951
1913	Wilber Judson	Aug. 8, 1951
1916	C. A. Lemke	July 31, 1951
1944	William H. Munds	Unknown
1928	Thomas Murphy	Unknown
1944	Morton T. Pawel	Unknown
1940	Lawrence E. Riddle	Aug. 9, 1951
1919	A. M. Strong	July 14, 1951
1945	C. S. J. Trench	Aug. 20, 1951
1920	Walter B. Wilson	May 21, 1951

Proposed for Membership
MINING BRANCH, AIME

Total AIME membership on Aug. 31, 1951, was 17,122; in addition 2511 Student Associates were enrolled.

ADMISSIONS COMMITTEE

Thomas G. Moore, Chairman; Carroll A. Garner, Vice-Chairman; George B. Carless, F. W. Hanson, Albert J. Phillips, Lloyd C. Gibson, R. D. Mollison, John T. Sherman. Alternates: A. C. Brinker, H. W. Hitzrot, Plato Malozemoff, Ivan Given, T. D. Jones, and W. A. Clark, Jr.

Institute members are urged to review this list as soon as the issue is received and immediately write the Secretary's Office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified. Objections must be received before the 30th of the month on Metals and Mining Branches.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Arkansas
Heber Springs—Hoskins, Ralph L. (M)

California
Lemoore—Gong, Chung C. (J) (R. C/S—S-J)

Colorado
Cripple Creek—Slothower, Ben H. (J) (R. C/S—S-J)
Grand Junction—Lindblom, Raymond A. (M) (R. C/S—J-M)
White Pine—Botelho, John B. (M) (R. C/S—S-M)

Delaware
Wilmington—Hockman, Edwin L. (J) (C/S—S-J)

Florida
Pierce—Wayman, Cooper H. (J)

Idaho
Hailey—Milner, Carlos E., Jr. (J) (R. C/S—S-J)

Illinois
Chicago—Isenberg, Nathan (M)
Chicago—Jacobs, Carl B. (M)

Kentucky
Martin—Mullins, William H. (J)

Michigan
Standish—Hagley, Albert W. (J)
Wetmore—Knox, James W. (J)

Minnesota
Ely—Lindgren, Donald W. (J)
Minneapolis—Jokela, William V. (J)

Missouri
Clayton—Krummel, William J., Jr. (J) (R. C/S—S-J)
Potosi—Hanson, William L. (M)
Rolla—Marinkovic, Sergio F. (J) (R. C/S—S-J)

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Silver City—Stuve, Ralph G. (J)
Vanadium—Hodges, Paul A. (J) (C/S—S-J)

North Carolina
Murphy—Bourne, Francis C. (M)

Ohio
Akron—Van Orden, Paul W. (A) (R. C/S—J-A)
Cleveland—Sylvester, George R. (M)

Oregon
Albany—Butner, Daniel W., Jr. (J) (R. C/S—S-J)

Pennsylvania
Ashland—Gilroy, Francis H. (M)
Bethlehem—Weitz, John H. (M) (R. C/S—J-M)
Mahanoy City—Davies, John W. (M)
Pittsburgh—Fiedler, William M. (M) (R. C/S—S-M)
Pittsburgh—Kingsley, Harry D. (M)
Pottsville—Long, Ralph J. (J)
State College—Brune, Arthur W. (M) (C/S—A-M)
Sybertsville—Markle, Donald, Jr. (M)

Utah
Kanab—Holmes, J. Mark (M)

Virginia
Austinville—Kellogg, Arthur D. (J) (C/S—S-J)

Washington
Holden—Crial, Richard S. (J) (C/S—S-J)

West Virginia
Princeton—Carter, James D. (J) (R. C/S—S-J)

Wisconsin
Milwaukee—Kjelgaard, Axel W. (M)

Wyoming
Casper—Wallway, Marvin J. (M) (C/S—A-M)

British East Africa
Kenya Colony—Worthy, Stanley R. (A)

Canada
Montreal—Read, Reginald F. V. (A)

Central America
Managua, Nicaragua—Almazan, Carlos C. (M) (R. C/S—S-M)

England
Carlisle—Parkinson, William P. H. (M)

Finland
Helsinki—Runolinna, Urmas O. (M)

Greece
Aliveri—Young, Horace C. (M)

Honduras
Tegucigalpa—Juilland, Paul G. (M)

Ireland
Dublin—Creedon, Cornelius J. (A)

Mexico
Col. del Valle—Burnham, J. Kellogg (A)
San Luis Potosi—Johnson, Stanley W. (J)
San Luis Potosi—Pickard, Greenleaf W., Jr. (A)
San Luis Potosi—Prado, Jose J. (A)

Northern Rhodesia
Chingola—Hall, William B. (J)
Kitwe.—Gray, Roy F. (A)

Peru
Tacna—Barreda-Moller, Alfonso (J)
Tacna—Larrabure, Eugene C. (J)
Tacna—Quiedo-Kernan, Federico S. (J)

South Africa
N. Transvaal—Spence, Wilfrid I. (A)

South America
Peru—Saunders, Bill G. (J) (R. C/S—S-J)

Sweden
Morgardshammar—Norrman, N. Peter (M)

Venezuela
Ciudad Bolivar—Ellingsen, Robert L. (J) (R. C/S—S-J)

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Coming Events

Oct. 1-4, Assn. of Iron and Steel Engineers, annual convention, Hotel Sherman, Chicago.

Oct. 3-5, AIME, Petroleum Branch, fall meeting, Oklahoma City.

Oct. 8-12, National Safety Congress & Exposition, Palmer House, Stevens, Congress, and Morrison Hotels, Chicago.

Oct. 9-12, Scientific Apparatus Makers Assn., mid-year meeting, Recorder-Controller Section, Seaview Country Club, Absecon, N. J.

Oct. 10-12, Electrochemical Society, autumn national convention, Hotel Statler, Detroit.

Oct. 11-12, Joint Fuels Conference, AIME, Coal Div. and ASME, Fuel Section, Hotel Roanoke, Roanoke, Va.

Oct. 12, AIME, Eastern Section, Open Hearth Committee, Warwick Hotel, Philadelphia.

Oct. 15-17, AIME, Institute of Metals Div., fall meeting, Detroit-Leland Hotel, Detroit.

Oct. 15-18, Society for Non-Destructive Testing, Inc., annual meeting, Hotel Detroiter, Detroit.

Oct. 15-19, National Metal Congress & Exposition, Detroit.

Oct. 18-19, Scientific Apparatus Makers Assn., mid-year meeting, industrial instrument section, Seaview Country Club, Absecon, N. J.

Oct. 18-20, National Assn. of Corrosion Engineers, south central region, Corpus Christi, Texas.

Oct. 19-20, Engineers' Council for Professional Development, annual meeting, Hotel Statler, Boston.

Oct. 22, AIME, Chicago Section, Open Hearth Committee, Phil Schmidt's, Chicago.

Oct. 22-24, American Mining Congress, Metal and Nonmetallic Mining Convention, Biltmore Hotel, Los Angeles.

Oct. 22-27, Societe Francaise de Metallurgie, Congress, Paris, France.

Oct. 25-26, Credit Bureau of Circulation, annual meeting, Congress Hotel, Chicago.

Oct. 25-26, AIME, Southern California Section, fall meeting, Los Angeles.

Oct. 29-Nov. 3, AIME, fall meeting, Mexico City.

Oct. 30, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Nov. 2, AIME, Pittsburgh Local Section and Open Hearth Local Section annual off-the-record meeting. Wm. Penn Hotel, Pittsburgh.

Nov. 2, Illinois Mining Institute, annual meeting, Hotel Abraham Lincoln, Springfield, Ill.

Nov. 25-30, ASME, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Nov. 28-30, Scientific Apparatus Makers Assn., midyear meeting, laboratory apparatus, optical, nautical, aeronautical, and military instrument sections, Hotel New Yorker, New York.

Dec. 2-5, American Institute of Chemical Engineers, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Dec. 6-8, AIME, Electric Furnace Steel Conference, William Penn Hotel, Pittsburgh.

Dec. 11, AIME, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

Dec. 27-28, American Chemical Society, Div. of Industrial & Engineering Chemistry, symposium on nucleation, Northwestern University, Evanston, (Chicago).

Jan. 16-18, 1952, Society of Plastic Engineers, Inc., annual national technical conference, Edgewater Beach Hotel, Chicago.

Feb. 18-21, AIME, annual meeting, Hotel Statler, New York.

Mar. 3-7, ASTM, spring meeting and committee week, Hotel Statler, Cleveland.

Apr. 25-26, AIME, New England Regional Conference, Kenmore Hotel, Boston.

May 6-9, Scientific Apparatus Makers Assn., annual meeting, Edgewater Beach Hotel, Chicago.

June 23-27, ASTM, 50th anniversary meeting, Hotel Statler, New York.

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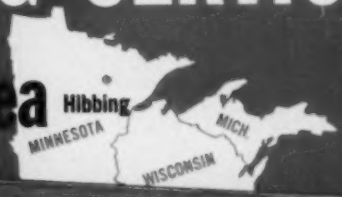

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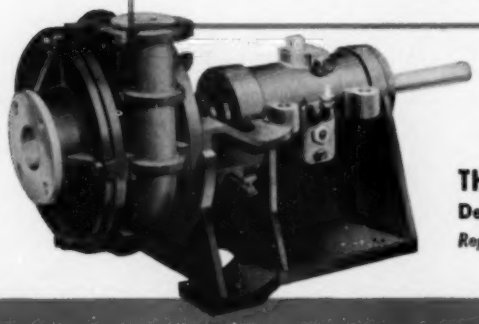

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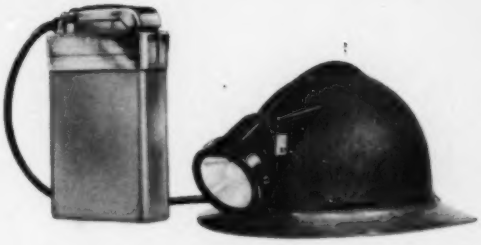

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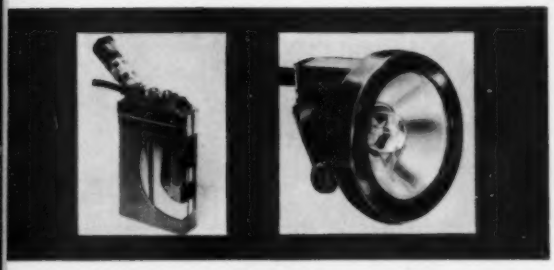

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